Modelling, Analysis and Design of Synchronous Buck Converter Using Soft Switching Technique for PV Energy System

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MODELING, ANALYSIS AND DESIGN OF SYNCHRONOUS BUCK CONVERTER USING SOFT SWITCHING TECHNIQUE FOR PV ENERGY SYSTEM

A Thesis submitted in partial fulfilment of the requirements for the degree of

Bachelor of Technology in Electrical Engineering

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CERTIFICATE

This is to verify the fact that that the thesis entitled Modelling, Analysis and Design of Synchronous Buck Converter Using Soft Switching Technique for PV Energy System, submitted by Abhishek Singh (110EE0232), Himansu Sekhar Sahoo (110EE0568), Partha Sarathi Mahala (110EE0204) in accomplishment of the demand for the honour of Bachelor of Technology in Electrical Engg. for the duration of session 2013-2014 at National Institute of Technology, Rourkela. A bona fide record of study exertion conducted by them underneath my guidance and supervision.

The students have completed all the suggested experiments.

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In my belief, the thesis is of standard necessary for the degree of a B.Tech. in Electrical Engineering.

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ABSTRACT

If we start forecasting in the view of electrical power generation, in the upcoming decade all the fossil fuels are going to be extinct or the worst they are going to be to a middle class man, so renewable energy power generation systems are going to make a big deal out of that. It is extremely important to generate and convert the renewable energy with maximum efficiency. The Photovoltaic (PV) energy system is a contemporary theory in use, which advances status because of growing reputation to study on different causes of energy over exhaustion of the conformist fossil fuels universal. The renewable sourced are commercialised to obtain power from the sun in efficiently and outfit them to the obtainable loads deprived of moving their presentation.

In our work, we present the exquisite design of Synchronous Buck Converter with the application of Soft switching Modelling to implement precise control design for the converter by the help of MATLAB/Simulink. The Synchronous Buck Converter thus designed is used for portable appliances such as mobiles, laptops, iPod's etc. Now, the converter concepts cast-off, usages extra MOSFET which eliminates losses of conduction which is originate conspicuously in the simple buck converter, thus performance of the converter is enhanced. But in this project our main intention is to interface the PV array with the Synchronous Buck Converter we designed and we will depict that our converter is more efficient than the conventional Buck converter in order of maintaining constant output voltage, overall converter efficiency etc. We also studied and modelled, MPPT for the given PV energy system and the simulations are carried out in MATLAB-Simulink environment. More, the relative study is proposed among the both synchronous and simple Buck converter.

At last we show that the output voltage remnants fixed irrelevance of fluctuations in load and source. And finally we see the performance of Synchronous Buck Converter, which is interfaced with PV array having the practical variations in temperature and irradiance will also maintain a constant output voltage throughout the response. All simulations are carried in MATLAB/Simulink software. The suggested converter is simulated in the MATLAB Simulink software and suggested converter is implemented practically to confirm the results of theory. Soft Switching control of synchronous Buck converter founded on PV energy system is experimented through ICs and investigational outcomes were concluded.

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Chapter-1

INTRODUCTION

1 INTRODUCTION

1.1 Inspiration

As the days go by, the demand of power is increasing gradually and on the contrary the resources used for power generation are becoming inadequate. Apart from the reason of inadequate resources, the methods used for power generation by fossil fuels are not even environment friendly and they devote an ultimate reason for global warming and greenhouse effect. So it is the time to initiate the usage of renewable energy resources on very large scale.

The three main available renewable energy resources are (i) Direct Solar Energy, (ii) Hydro Energy and (iii) Wind Energy. Hydro Energy generation and Wind Energy generation are of course two of the main sources of renewable energies, but the main disadvantage in Hydro Energy is that, it is seasonal dependent and in Wind energy is that it is geographical location dependent [1]. On the other hand Solar Energy is prevalent all over the globe and all the time. The amount of irradiance and temperature may vary from place to place and from time to time but under given conditions Solar Energy system can be implemented.

Solar Energy or PV energy system is the most most effective method to convert the solar radiated energy into electricity based on photo-voltaic effect. Despite of high initial costs, they are already have been implemented in many rural areas. In future the cost of the PV panel also may diminish, because of the advancing technology and also the competition between manufacturers. And therefore, the time is not so far that almost every middle class person can afford his own solar panel at home for at least some basic requirements. Thus PV Energy is going to play a vital role.

1.2 PV Energy

1.2.1 Photovoltaics (PV)

Photovoltaics is mainly defined as a technique for producing electrical power by using PV cells to transfer solar energy to electric current. The photoelectric effect causes photons of radiation to excite negative charge into a advanced energy level, letting them to carry the electrical current. The photoelectric effect is first understood by Alexndre-Edmound Becquerel in 1839.

The term photovoltaic represent working manner of a photo diode in which the driving current is completely due to the transduced solar energy..

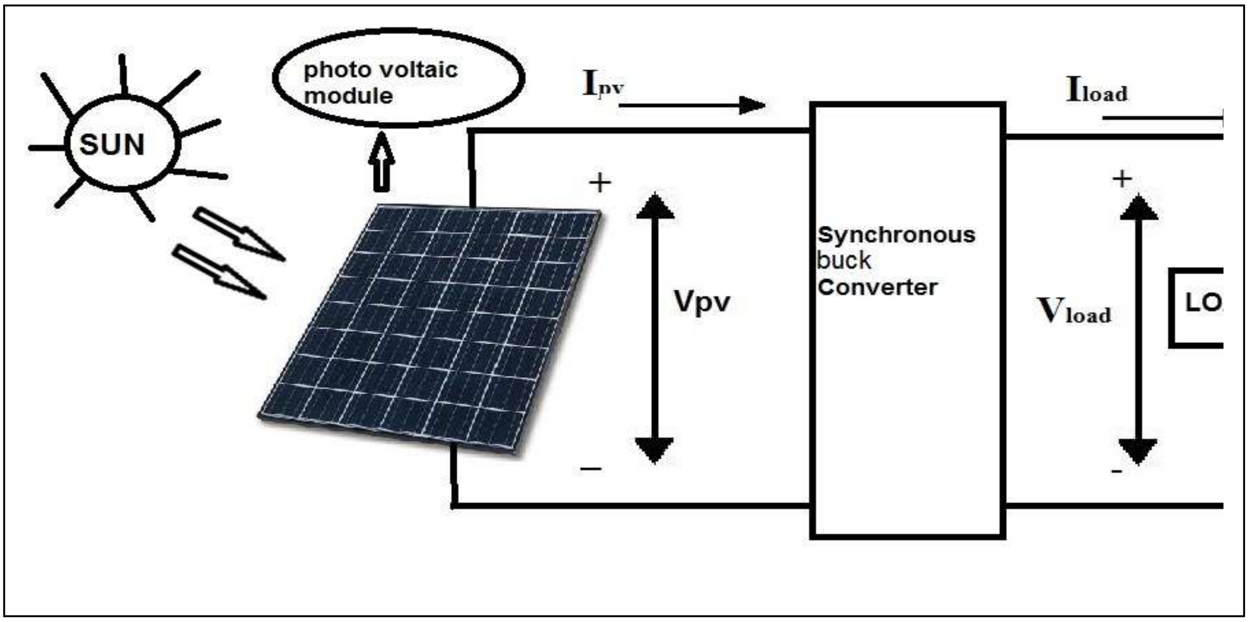

FIGURE 1 Schematic Diagram of PV Based Converter System. .

Solar panels yield DC power from solar light which is utilised to supply load or to refresh a battery-operated device. The initial use of photovoltaic was to supply circling satellites and other rocket, but today the greatest of the photovoltaic modules are implemented for network linked control generation. In this situation it is very important to transform the DC to AC. There is very small marketplace for off network energy for distant dwellings electrical cars,, automobiles, backup telephone booths, remote detecting, and defence of cathode in tubes.

Cells demands fortification and are typically packed inside a glass leaf tightly. When more electricity is required than a single cell may give, cells are electrically attached together in series to build photovoltaic array, or solar panels. A solitary unit is sufficient to supply an urgent handset, but for a home or a generating station the cells must be attached in combination as form panels.

1.3 Proposed Work Done overview

Various prose are utilised to perform the scheme which consists of data on photovoltaic arrays, PV energy systems, converters topology, variation in the performance of arrays with atmospheric conditions, etc. Reference [1]-[2] gives an overview about the applications of photovoltaic technology. Reference [3] gives us the data on the entire Indian Energy scenario particularly regarding with renewable energy sources. It enriched us on data on the potential and of solar energy use in rural applications. Reference [4] give details about technology of battery available in the world. Reference [5] states the converter requirement for photovoltaic applications. References [6]-[9] describe various such converters available for use. Reference [10] made us understand the phenomenon of soft – switching and some of the techniques are seen in reference [9].

1.4. Objectives of Thesis

At the end of the project, the objectives to be achieved are listed following:

1. To study the solar cell model and observe its characteristics.
2. To study the proposed synchronous DC-DC Buck converter and its operation.
3. To study the design of buck converter with controller with the help of Soft Switching techniques.
4. To study the comparison between the conventional Buck converter and the synchronous DC-DC Buck converter suggested in terms of effectiveness enhancement.
5. To study the Maximum Power Point Tracking (MPPT) algorithms of PV Array model and to implement in Simulink Environment.
6. To validate the experimental results obtained from the laboratory set-up and to analyse the results with the simulated results in the MATLAB-Simulink Environment.

1.5 Thesis Organisation

The thesis is divided into six sections including the section of introduction. Each section is distinct from one another and is stated laterally by the required knowledge and concept to represent it.

Chapter No.2 deals with PV Array Characteristics and its modelling. First, the equivalent mathematical modelling of the solar cell is made after studying various representations and simplification is made for our purpose. Then PV and IV characteristics curves for both fixed temperature and fixed irradiation for the equivalent model is studied in MATLAB Simulink model using equation corresponding to that model.

Chapter No. 3 is results and discussion section, in which all simulation results of PV Characteristics, IV characteristics at different constant values of temperature and irradiation and also different values of series resistance is shown.

Chapter-2

PV-ARRAY CHARACTERISTICS

PV-ARRAY CHARACTERISTICS

2.1 Introduction

Learning and analysing PV Array characteristics plays a vital role when it comes to PV energy generation. These characteristics vary from one model to the other. But, however we in this section study the PV array characteristics for ideal PV Cell, which includes P-V & I-V features at fixed hotness and also PV & I-V features during fixed Irradiance. Meticulous study of these characteristics helps us to understand the functioning of PV Cell during the variations of temperature and irradiation which are the pioneer parameters for PV energy generation.

These characteristics obtained, not only helps us in understanding PV system, but also helps in the study of concept Maximum Power Point Tracking (MPPT) and also to obtain that point for maximum efficient operation of System. These topics are discussed in later chapters in detail.

2.2 PV Array Modelling

The solar panels or PV arrays are typically manufactured from minor chunks of lone solar cell elements. They provide rated production current and voltage that can be used for a specified set of atmospheric data. The esteemed current depends upon amount of parallel ways of solar cells and the esteemed voltage of the panel be subject to upon the amount of series connected solar cells in each of parallel ways. An individual solar cell is a photo diode. The corresponding circuit model of PV cell comprises of a dependent current basis on radiation and hotness, a diode conducting opposite overload current, series advancing resistance of the cell.

The Figure 2, is an approximated version of actual single cell equivalent circuit. The output current (Ipv) and the output voltage (Vpv) are dependent on the solar irradiation and temperature and also the saturation current of diode. For that single cell, Ipv and Vpv are calculated by the equations given below:

EQUATIONS:

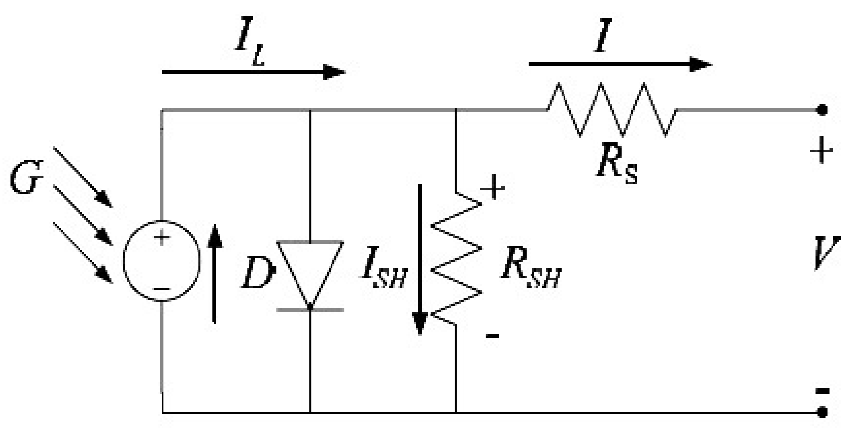

Figure 2 Equivalent Circuit of PV Cell

Module Photo Current

$$I_L = I_L(T_1) + K_0(T-T_1) \quad (1)$$

$$IL = I_{SC}(T_{1,nom}) \frac{G}{Gnom} \quad (2)$$

$$K0 = \frac{Isc(T2)-Isc(T1)}{(T2-T1)} \quad (3)$$

Module Reverse Saturation Current:

$$I0(T1) = \frac{Isc(T1)}{(e^{\frac{qVoc(T1)}{nkT1}}-1)} \quad (4)$$

The module saturation Current I_0 depending on cell temperature as given by:

$$Io = Io(T1) * \left(\frac{T}{T1}\right)^{\frac{3}{n}} e^{\frac{qVq(T1)}{nk\left(\frac{1}{T}-\frac{1}{T1}\right)}} \quad (5)$$

The output current of solar cell is:

$$I = I_L - I_0\left(e^{\frac{q(V+IR_S)}{nkT}} - 1\right) \quad (6)$$

Due to help of above equations, subsystems are created in MATLAB/Simulink environment to obtain PV cell equivalent subsystem and with the help of obtained subsystem PV Characteristics are obtained.

Chapter-3

SYNCHRONOUS BUCK CONVERTER AND IT'S EFFICIENCY

SYNCHRONOUS BUCK CONVERTER AND IT'S EFFICIENCY

3.1 Synchronous Buck Converter Design

The following parameters are considered for design:

- V_{in} = 12 V
- V_{out} = 3 V
- I_{load} = 1 A
- F_{sw} = 200 KHz
- Duty cycle (D) = V_{in}/V_{out} = 0.25
- Assume $I_{ripple} = 0.3*I_{load}$ (typically 30)
- The switching frequency is nominated at 200 KHz.
- The current ripple will be restricted to 30% of supreme load

Parameters Calculations:

a) Inductance Calculation:

Inductor and capacitor plays a major role in dc-dc converters acting like a low pass filter both combined. Inductance helps in limiting the ripple in the output current.

For an inductor,

$$L = \left(\frac{V_{in}}{V_{out}}\right) * \left(\frac{D}{F_{SW} * I_{ripple}}\right)$$

$$L = \left(\frac{12V}{3V}\right) * \left(\frac{0.25}{200KHz * 0.3A}\right) \qquad (7)$$

L=37.5 µH

Assume 37.5 µH, 2 amps inductor has a resistance of 0.05Ω. The energy dissolute owing to Cu losses is: $(Iload)^2$* ES2R = 0.05 watts

(b) Output Capacitor Calculation:

The voltage wave through the output capacitor is the addition of ripple voltages due to the Effective Series resistance (ESR), the voltage drop owing to the load current that necessity be provided by the capacitor as the inductor is settled, and the voltage ripple due to the capacitor's Effect Series Inductance". The ESL requirement is usually not specified by the capacitor seller. For this instance, we will assume that the ESL is null.

As switching frequencies rise, the ESL ratings will convert further significant. For capacitance,

$$\Delta V = \Delta I * \left(ESR + \frac{\Delta T}{c} + ESL\right) * \Delta T \tag{7}$$

The expression presented here displays that we are resolving an expression with many variable, ESR, C, and ESL. A sensible method is to eliminate relations that are not important, and then brand a sensible estimation of the greatest significant stricture that we can control, ESR. The capacitor ESR rate was nominated from a seller's catalogue of amps rated capacitors. Assumed the ripple current and the objective output voltage ripple, an ESR value of 0.05Ω was designated from a list of capacitors rated for 0.3 amp ripple current.

Assume voltage of ripple to be 50mV

Given δ I=0.3 A, ESR=0.05Ω

From that, δ T=58µsec

Assume ESL=0

Then, we will compute the mandatory capacitance of the output capacitor specified the wanted output voltage ripple is well-defined as 50 mV. Then,

$$c = \frac{\Delta I * \Delta T}{\Delta V - (\Delta V - ESR)} \tag{8}$$

The expression's denominator (δV-(δ I*ESR)) demonstrates that the capacitor's

ESR rating is further significant than the capacitance value. If the designated ESR is very high, the voltage because of the ripple current will equivalent or surpass the mark output voltage ripple.

We have a divide by 0 matter, representing that an unlimited output capacitance is requisite. If a sensible ESR is designated, formerly the real capacitance value is sensible.

Polymer Electrolytic Capacitor with 500µF and ESR of 0.05Ω is used.

Power loss in the capacitor is $(I_{ripple})^2$*ESR=0.0045 watts.

c) Input Capacitor:

The poorest case ripple current happens once the duty cycle is 50% and the nastiest case ripple current on the contribution of a buck converter is around one half of the capacity current. Similar the output capacitor, the input capacitor assortment is chiefly verbalized by the ESR obligation desirable to meet voltage ripple supplies. Typically, the contribution voltage ripple necessity is not as severe as the output voltage ripple condition. Now, the extreme input voltage ripple was definite as 200 mV. The input ripple current score for the input capacitors may be the greatest significant standards for choosing the input capacitors. Frequently the input ripple current will surpass the output ripple current.

Input ripple current is assumed to be *Iload*/2

Input voltage ripple is accepted to 200mV

ESR value of capacitor is 0.12Ω

Compute capacitance:

$$C_{in} = \Delta T * \left(\frac{V_{ripple}}{capacitor\ ESR}\right)$$

$$C_{in} = 96.6\ \mu F$$

Power loss at the capacitor is $(I_{ripple})^2$*ESR= 0.0107 watts

d) Diode Selection:

The diode's regular current is same to the load current product the share of time the diode is directing.

The duration the diode is on is: (1 - duty cycle)

ID = (1-D)* *Iload*= 0.75 amps

Max diode reverse voltage is 12 volts, for this, select schottky diode 1N5820,

20 V and 3 amps rating.

Forward voltage drop assumed at peak current is assumed to be 0.4 volts

Power dissipation in the diode is *VF***Id*=0.3 watts

e) MOSFET Selection:

To make simpler the gate-drive electric circuit for the MOSFET, a P-channel switch was designated. An N-channel switch wanted a gate drive circuit that includes a technique to control the gate voltage around the supply. The price of a equal translator and control drive will overshadow the investments of by means of an N-channel device as opposed to a P-channel device. A 20 volt MOSFET was not designated since the obtainable switches in the catalogue had extreme gate to source voltage ratings of individual 12 volts. With a 12 volt input voltage, the functional gate volts may surpass the MOSFET ratings A 30 volt MOSFET was designated on the base of the 20 volt gate to source requirement.

For above design parameters for converter design, select N-channel MOSFET for comfort of lashing gate. Select 30 V, 9.3 amps with low typically 0.02Ω.

Assume Trise=Tfall= 50nsec

Conduction loss= (*Id*)2**Rds*(on)*D= 0.005watts

Switching loss= 0756 W

$$P_{switching\ loss} = \left(V * \frac{I_D}{2} * T_{on}T_{off}F_{SW}\right) + \left(C_{on\ loss} * V^2 * F_{SW}\right) \tag{9}$$

(Assume *Coss*=890pF)

Total loss= 0.005+0.0756= 80mW.

3.2 Synchronous Buck Converter Efficiency and Comparison

A) Buck Converter Efficiency:

- *Pout*= 3 watts (3V @ 1a)
- Inductor loss= 50mW
- Losses in output capacitor= 4.5mW
- Losses in input capacitor= 10.8mW
- Diode loss= 300mW
- MOSFET loss=80mW
- Total losses= 445mW
- Converter efficiency = (*Pout?(Pout*+total losses)*100= 85.6%

Here diode forward voltage drip (0.4 V) causes the overall losses of 60%. The converter effectiveness could be elevated if the diode's forward voltage drip resolve be depressed.

B) Synchronous Buck Converter Efficiency:

This portion displays a Synchronous Buck converter. It is like to the preceding conventional buck converter, excluding the diode is connected in parallel with a new transistor. It is named a synchronous buck converter since MOSFET M2 is switched on then off synchronously with the process of the main switch M1. The knowledge of a synchronous buck converter is to custom a MOSFET as a rectifier that has very short forward voltage drop as related to a normal rectifier. By dropping the diode's voltage drop, the over-all productivity for the buck converter can be enhanced. The synchronous rectifier (MOSFET M2) needs an other PWM signal that is the counterpart of the main

PWM signal. M2 is on once M1 is off and reverse is true. This pwm arrangement is called Complementary PWM.

P_{out} = 3W (3 V @ 1 A)

Choose N-channel MOSFET with R_{ds}(on) = 0.0044Ω, Use similar method for loss calculation as stated above.

Transmission loss= (*Id*)2**Rds*(on)*(1-D) = 15mW

Primary MOSFET (S1) loss= 10mW

Resonant capacitance(*Cr*) loss = 10mW

Resonant Inductance(*Lo*) loss= 50mW

Losses of Output capacitor (*Co*) =4.5mW

MOSFET(S2)= 75mW

Diode(D) loss= 5

Inductor(*Lr*) loss= 20mW

Whole Loss = 190mW

Converter efficiency= (3/3+0.190)*100= 94.8%

NOTE: The relative graph of efficiency among Buck Converter and Synchronous Buck converter is exposed in RESULTS AND DISCUSSION section.

Chapter 4
Maximum Power Point Tracking

4. MAXIMUM POWER POINT TRACKING (MPPT)

4.1 Introduction

Maximum power point tracking (MPPT) is a practise that is used in solar battery-operated stallions and identical procedures use to get the extreme conceivable power from one or more photovoltaic equipments, classically solar panels, however optical power broadcast systems can profit from comparable technology. Solar cells need a compound relationship among solar radiation, temperature and total resistance that products a non-linear production efficiency which can be examined founded on the I-V curve. It is the determination of the MPPT scheme to model the output of the cells and put on the good resistance (load) to get extreme power for somewhat given ecological circumstances. MPPT procedures are characteristically combined into an electrical control converter scheme that pro-vides voltage or current adaptation, sifting, and directive for heavy various loads, with power networks, sequences, or motors.

The Maximum Power Point Tracker (MPPT) is desirable to enhance the quantity of power gotten from the solar panel towards the power source. The production of a solar panel is considered by a characteristic curve of voltage versus current, named the I-V curve. The supreme power point of a solar panel is the point laterally the I-V curve that agrees to the extreme output power conceivable for the panel. This magnitude can be calculated by estimating the extreme area underneath the I-V curve. MPPT's are utilised to precise for the differences in the I-V features of the solar panels The I-V curve will change and distort dependent upon such things as high temperature and lighting..

Meanwhile the extreme power point rapidly transfers as illumination conditions and weather change, a equipment is desirable that treasures the supreme power point and adapts that voltage to a voltage equivalent to the system voltage. Price is a chief issue when determining to use solar power as a source. A buyer wants to extract the extreme energy per rupee consumed on a panel. Solar panel do contemporary an stimulating difficulties in the transmission of power to a load, though. Aimed at additional obvious clarification, we can state that solar array have a nonlinear IV characteristic, with a different maximum power point (MPP), which be contingent on the ecological factors, such as temperature and radiation. In order to uninterruptedly produce extreme power from the solar plates, they have to function at MPP in spite of the unavoidable variations in the atmosphere. Therefore the supervisors of all solar electrical converters employment some technique for maximum power point tracking (MPPT). Over the previous year's several MPPT methods have been available. The three procedures that anywhere found most appropriate for large and medium size photovoltaic (PV) claims are perturb and observe (P and O), incremental conductance (InCond) and fuzzy logic control (FLC). Here in this scheme we suggest P and O method, which overwhelmed the poor presentation when the radiation vagaries constantly. This model was validated with simulations.

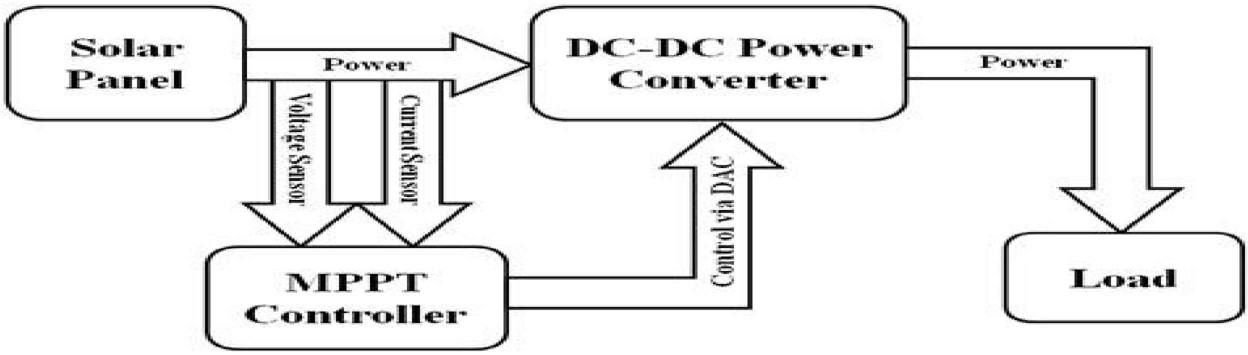

Figure 3: Block diagram of DC-DC converter incorporating MPPT control

4.2 P and O Method

4.2.1 Motivation

MPPT algorithms are essential in PV submissions since the MPP of a solar array differs with the radiation and hotness, so the usage of MPPT schemes is mandatory in directive to get the extreme power from a PV panel. Since many years lots of methods are used to treasure the MPP have been technologically advanced and printed. These practises vary in many facets such as obligatory devices, intricacy, cost, range of efficiency, conjunction speed, precise tracking when radiation and/or hotness change, hardware required for the application or admiration, among others. Among these methods, the P & O and the InCond procedures are the greatest shared. These methods have the benefit of an calm carrying out but they similarly have disadvantages. Other methods founded on different ideologies are fuzzy logic control, neural grid, fractional open circuit voltage or short circuit current, current sweep, etc. Greatest of these technique harvest a local extreme and about, like the fractional open circuit voltage or short circuit current, stretch an approached MPP, not the precise one. In standard circumstances the V-P curve has only one extreme, so it is not a problematic. Though, if the solar panel is partly dappled, there are many maxima in these arcs. In directive to dismiss this difficulty, some procedures have been applied as in.

4.2.2 Hill Climbing Techniques

Individually P and O and InCond procedures are founded on the “hill-climbing” standard, which contains of touching the action point of the PV panel in the path in which power gains. Hill climbing procedures are the maximum general MPPT approaches due to their comfort of application and decent presentation when the radiation is fixed. The benefits of two approaches are the effortlessness and little computational. The inadequacies are also renowned: fluctuations about the MPP and they can get misplaced and track the MPP in the wrong way in quickly altering impressive conditions.

4.2.3 P and O Algorithm Implementation

The P and O procedure is also named “hill-climbing”, nonetheless both terms mention to the similar procedure liable on how it is applied. Hill-climbing includes a worry on the duty cycle of the buck converter and P and O a agitation in the working voltage of the DC connection among the PV panel and the buck converter. In the situation of the Hill-climbing, disturbing the duty cycle of the buck converter suggests adjusting the voltage of the DC connection among the PV panel and the buck converter, so both terms refer to the identical practise.

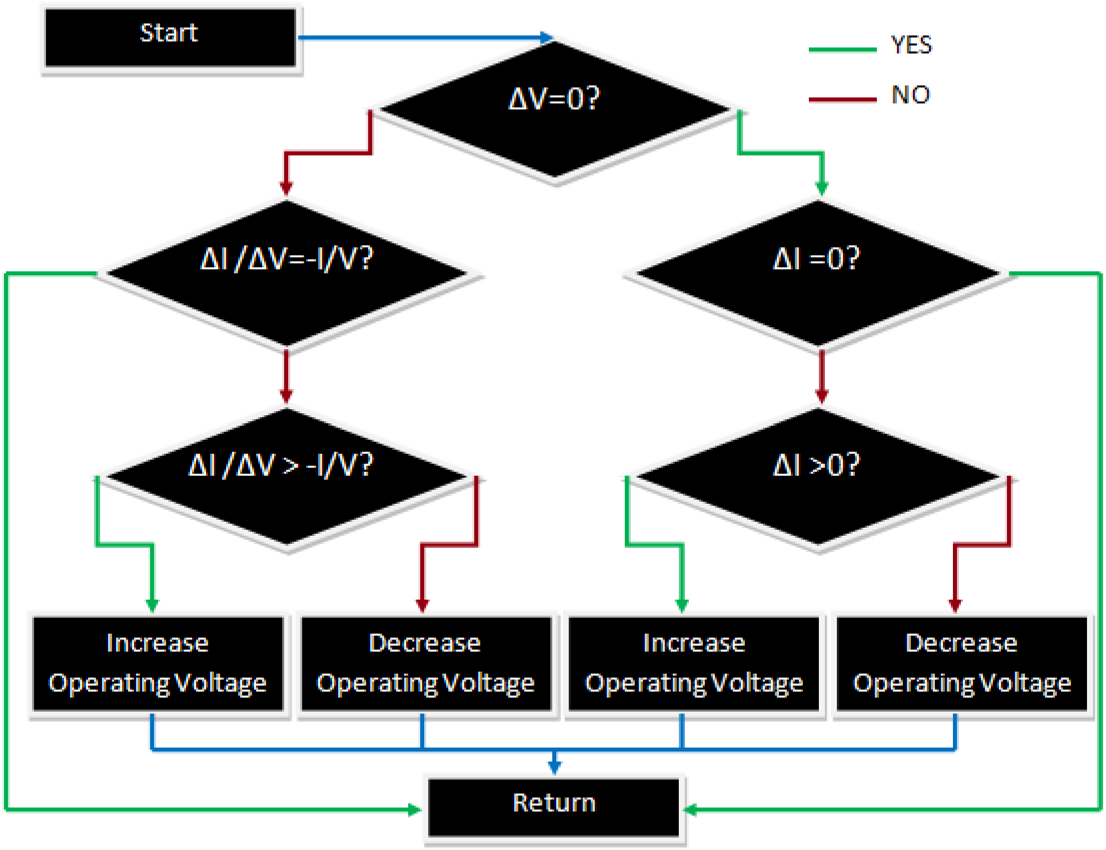

Figure 4: Flow Chart of P and O Algorithm.

In this technique, the sign of the previous agitation and the sign of the previous increase in the power are cast-off to choose what the following agitation should be. As described in Fig. 4, on the left-hand of the MPP increasing the voltage upsurges the power while on the right-side decreasing the voltage growths the power. If there is an increase in the power, the agitation would be kept in the similar way and if the power reductions, then the following agitation would be in the conflicting way. Founded on these truths, the procedure is applied. The procedure is recurrent pending the MPP is touched. Then the working point fluctuates about the MPP. This difficulty is shared also to the InCond technique, as was referenced later. A arrangement of the procedure is exposed in Fig. 4.

In P and O and InCond structures, how quickly the MPP is touched be contingent on the scope of the increase of the orientation voltage. The disadvantages of these practises are chiefly two. Firstly the main one is that they can effortlessly misplace track of the MPP if the radiation varies quickly. In situation of step variations they touch the MPP very healthy, since the variation is rapid and the arc does not keep on varying. Though, when the radiation changes subsequent a slope, the curve in which the processes are founded vagaries incessantly with the radiation, so the variations in the voltage and current are not alone due to the agitation of the voltage.

CHAPTER 5

Soft-Switching of DC-DC buck Synchronous Converters

Soft-Switching in DC-DC buck Converters

5.1 Concept of soft switching:

Conventional PWM converters operate on hard switching phenomenon where voltage and current pulses, during their transition from higher to lower values or lower to higher values interact with each other and cause power losses called switching losses and generate a substantial quantity of electromagnetic intrusion. Switching losses rise due to output capacitance of transistor, capacitance of diode, reverse recovery diode. It is experiential that switching losses are relative to switching frequency. So, developed switching losses cause to the restraint of switching frequency. Due to extensive variety of harmonics existing in PWM waveform, a great Electro Magnetic Interference (EMI) happens. EMI also fallouts from extraordinary current spikes produced by diode recovery.

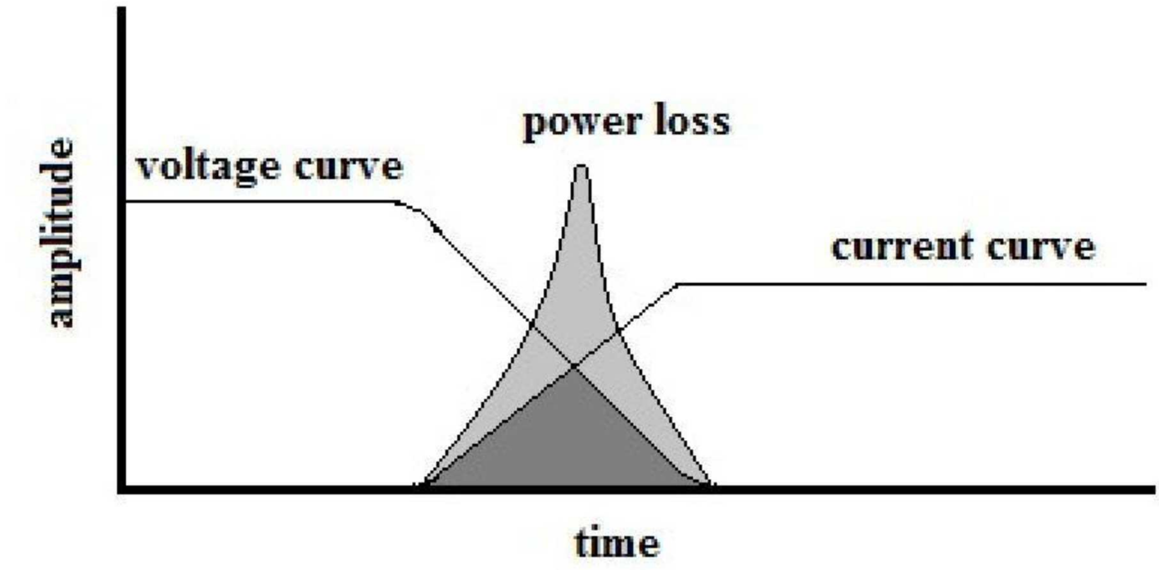

Figure 5: hard switching phenomenon

Switching losses and EMI can be reduced by using soft switching techniques at the expense of stress on the device. If the semiconductor device is made to turn off or turn on when current or voltage is zero, then the product of voltage and current during transition is zero which leads to no loss in power. Thus switching losses are removed and the MOSFET can be made to function at high switching frequencies. Magnitude and heaviness of the MOSFET also reduces because of no requirement of heat sink.

5.2 Difficulties of Hard-Switching

- Switching losses
- Device strain, thermal organisation
- EMI because of more di/dt and dv/dt
- Power loss in lost L and C

5.2.1 Probable Solutions

- Snubbers to decrease di/dt and dv/dt
- Circuit layout to reduce lost inductances
- Gate drive
    - circuit layout
    - switch on / off rapidity
- **Soft switching to attain ZVS or ZCS** typically no variation in losses

5.2.2 Advantages –

- Less losses
- Less EMI
- Permits high frequency process

5.3 Types of soft switching techniques

The soft switching techniques are widely categorized into two types namely

- Zero Voltage Switching(ZVS)
- Zero Current Switching(ZCS)

5.3.1 Zero Voltage Switching(ZVS):

The technique in which the MOSFET or any other semiconductor turns on at zero voltage is called ZVS. ZVS is used during turn on of the device. Initially the primary MOSFET S is off and the secondary MOSFET S_1 is on. Hence current through primary switch is zero whereas voltage will not be zero. During switch on voltage is ended zero across the switch and current is assumed some time delay such that current begins to rise after the voltage becomes zero. This is called ZVS.

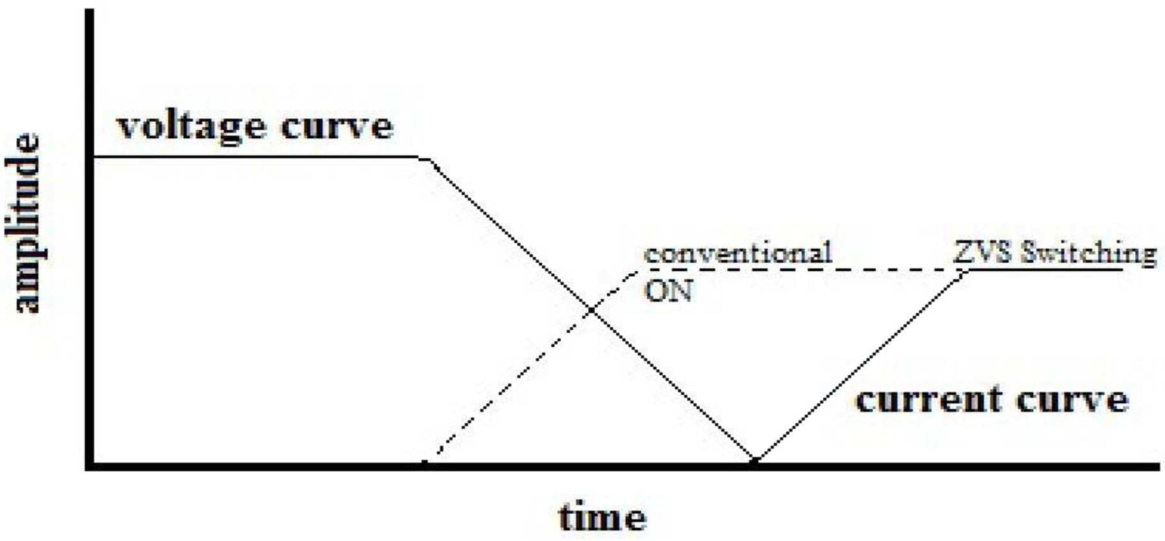

FIGURE 6: ZERO VOLTAGE SWITCHING (ZVS)

Turn on

- Switch voltage made to zero before gate voltage is supplied
- Ideal, no loss changeover

Turn off

- Less loss changeover
- Parallel capacitor like a less loss snubber

Favoured arrangement for very higher frequency operations consuming MOSFETs

FIGURE 7: switch on and switch off of Zero Voltage Switching(ZVS)

5.3.2 Zero Current Switching(ZCS):

This technique in which MOSFET or any other semiconductor device turns off at zero current is called ZCS. ZCS is used during turn off of the device. Originally the device is conducting. Hence current passing over the device is non zero and the voltage crosswise the device is 0. In the ZCS method, current is brought zero and the voltage is increased only after the current is zero. Thus there is no power loss during turn off of the device.

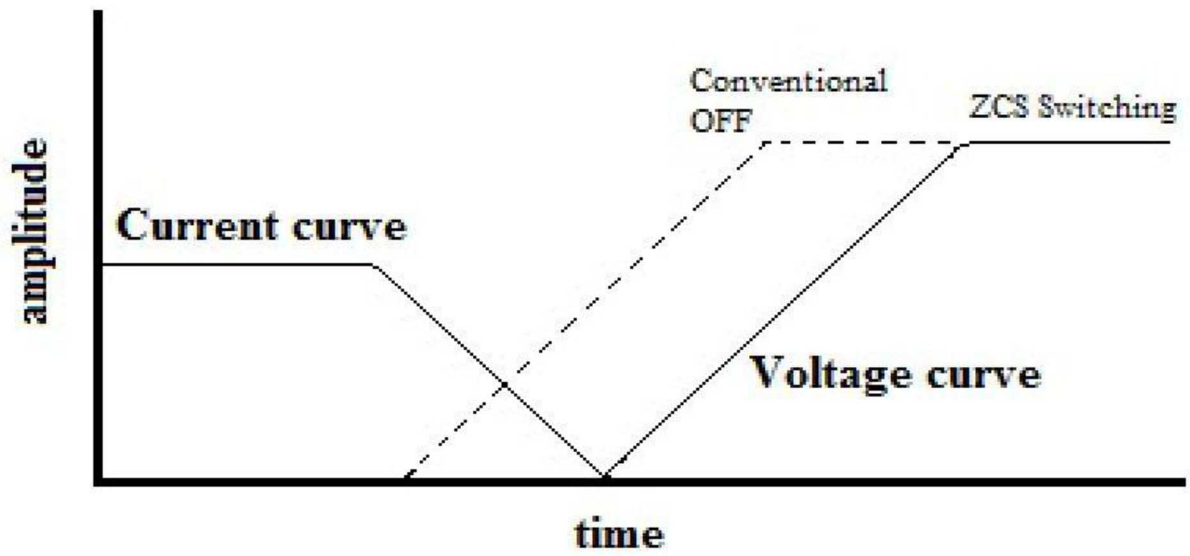

FIGURE 8: ZERO CURRENT SWITCHING(ZCS)

Turn off

- Switch current transported to zero earlier gate voltage is detached
- Zero loss changeover. Lossless process

Turn ON

- Low loss change
- Series inductor by way of a less loss snubber
- Power in junction capacitance is misplaced

Finest suitable for converters through IGBTs due to end current at turn-off

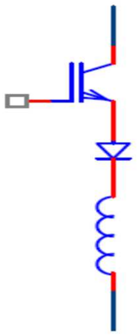

FIGURE 9: ZERO CURRENT SWITCHIN(ZCS)

5.4 Soft switching of Synchronous Buck Converter

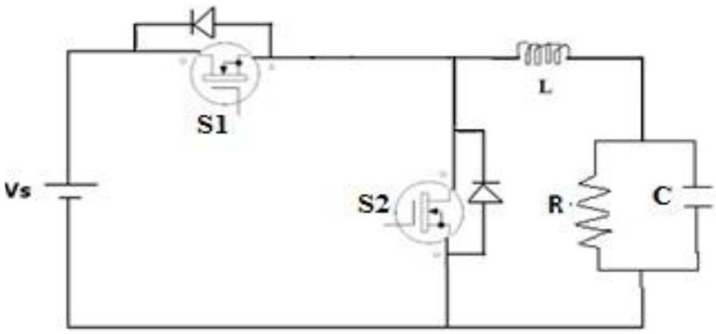

FIGURE 10: SYNCHRONOUS BUCK CONVERTER

In this converter two MOSFETS are used which are synchronized. The second MOSFET is used in place of diode so that conduction loss is minimised. But in this converter, no auxiliary circuit is present for reducing the switching losses. Thus this converter can be used only for low switching frequency applications.

At t=0, T^{+} is turned off

$$v_{C^+}(0) = 0$$

$$v_{C^-}(0) = V_d$$

$$v_{C^+} + v_{C^-} = V_d$$

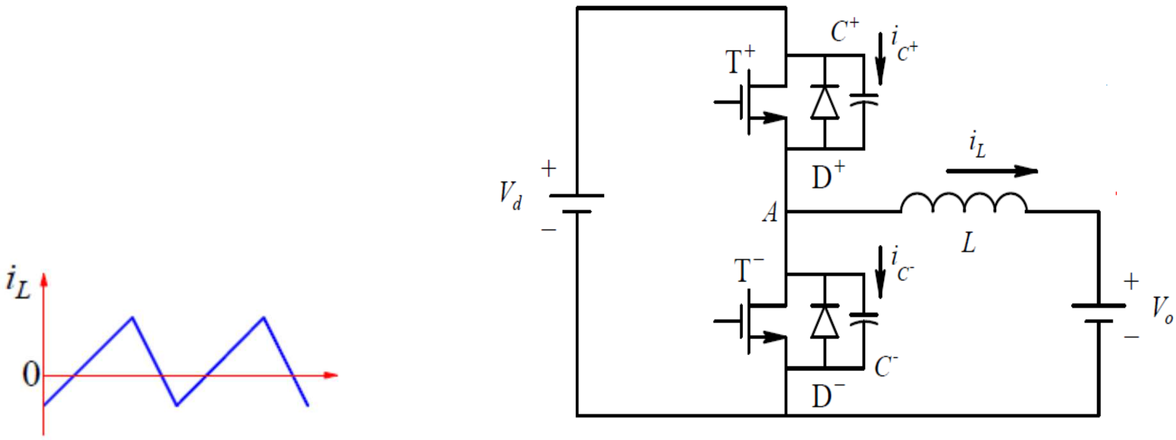

FIGURE 11: SOFT SWITCHING OF SYNCHRONOUS BUCK CONVERTER

$$Since \quad v_{C^+} + v_{C^-} = V_d$$

$$C_s \frac{dv_{C^+}}{dt} + C_s \frac{dv_{C^-}}{dt} = 0$$

$$\therefore \; i_{C^+} + i_{C^-} = 0$$

$$Also, \; i_{C^+} - i_{C^-} = i_L$$

$$\therefore \; i_{C^+} = -i_{C^-} = \frac{i_L}{2}$$

$$v_{C^+} = 0 \nearrow V_d$$

$$v_{C^-} = V_d \searrow 0$$

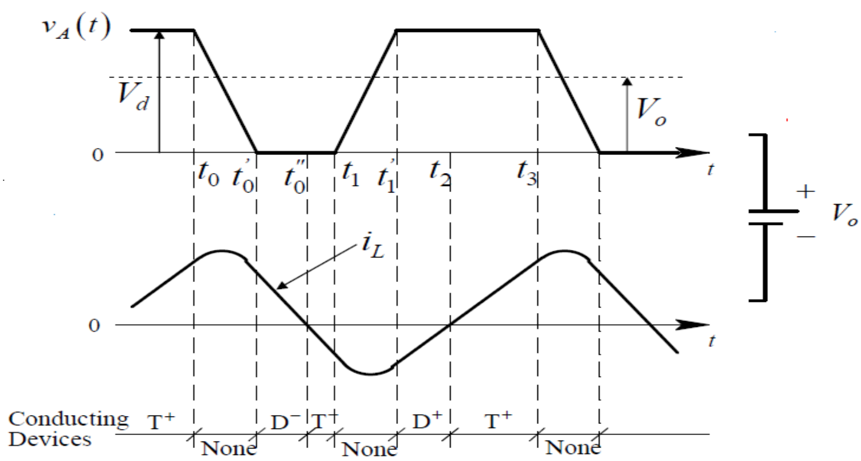

FIGURE 12: ZERO VOLTAGE SWITCHING TRANSITION WAVEFORM IN SYNCHRONOUS BUCK CONVERTER

Chapter-6

SIMULATION OBSERVATIONS RESULTS AND DISCUSSION

6.1 PV System

In direction to verify the proposed model of small PV system of 19.2 W is considered. This segment reveals the simulation outcomes of solar panel using the equations depicted in last section in MATLAB/Simulink environment. In this section we will explore the characteristics of PV array with the change in irradiance and temperature and we will observe the changes in output power and current

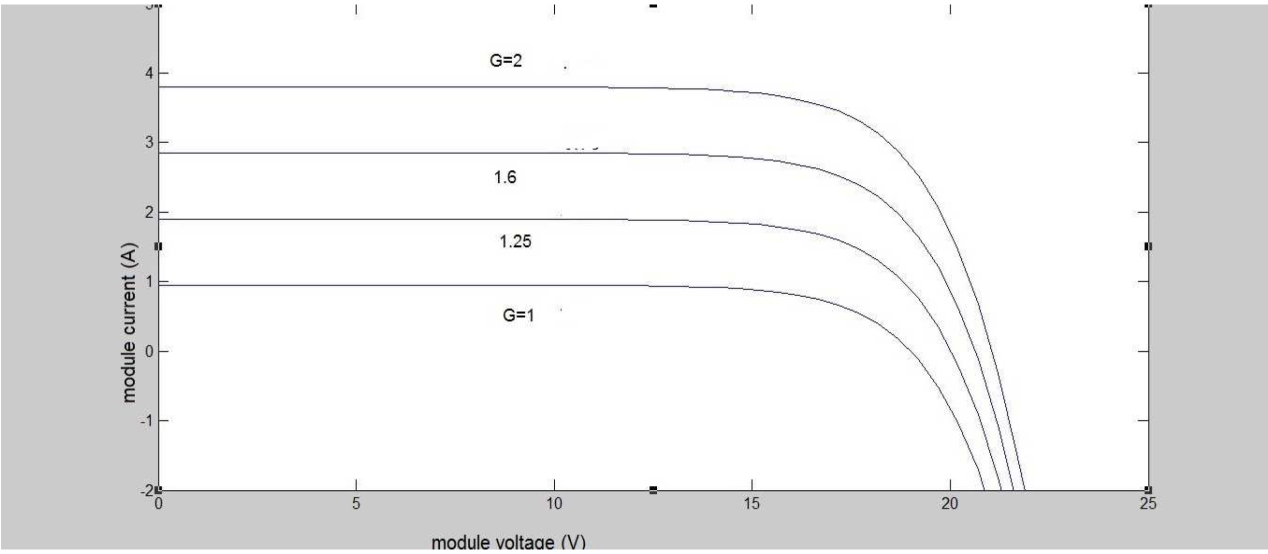

Fig. 13 depicts the variation of Module current with Module Voltage with the variation of irradiance (G=1, 1.25. 1.6 and 2 sun) on the module at the constant temperature i.e. of 25^0C

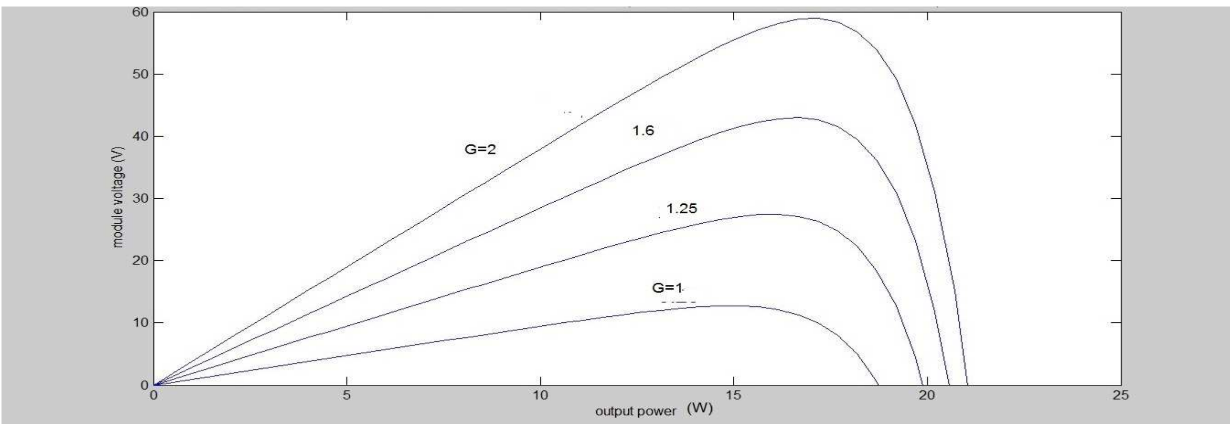

Fig. 14 depicts the variation of Module power with Module Voltage with the variation of irradiance (G=1, 1.25. 1.6 and 2 sun) on the module at the constant temperature i.e. of 25^0C.

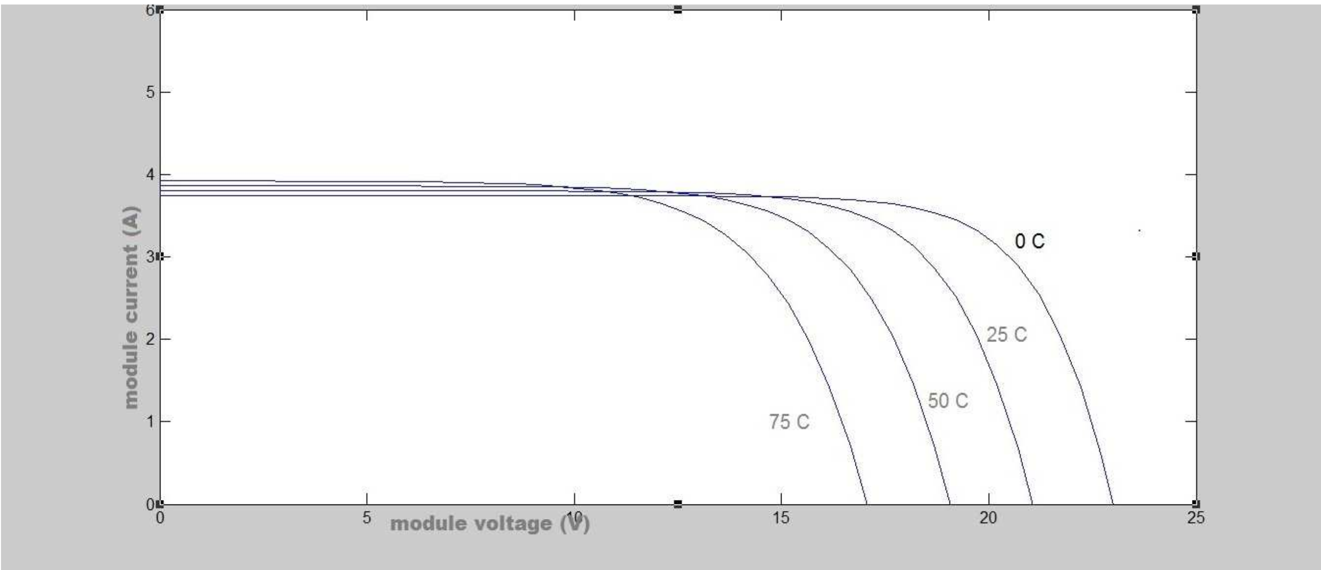

Fig. 15 depicts the variation of Module current with Module Voltage with the variation of temperature (T=0, 25, 50, 75^{0}C) on the module at the constant irradiance i.e. of 1000W /m^2

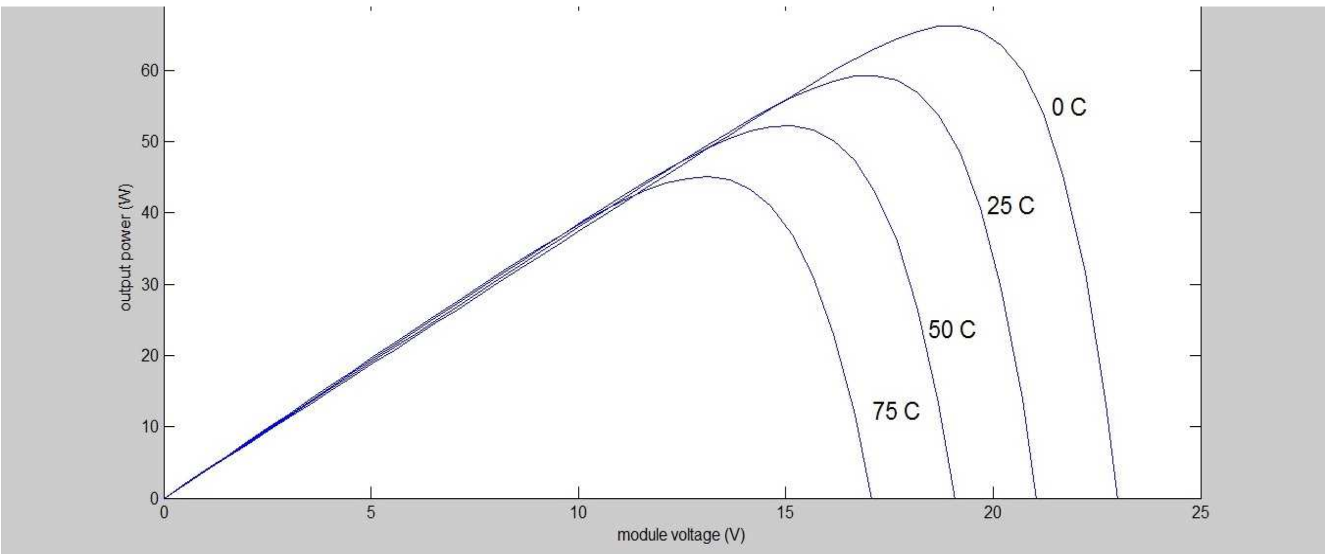

Fig. 16 depicts the variation of Module Power with Module Voltage with the variation of temperature (T=0, 25, 50, 75^{0}C) on the module at the constant irradiance i.e. of 1000W /m^2.

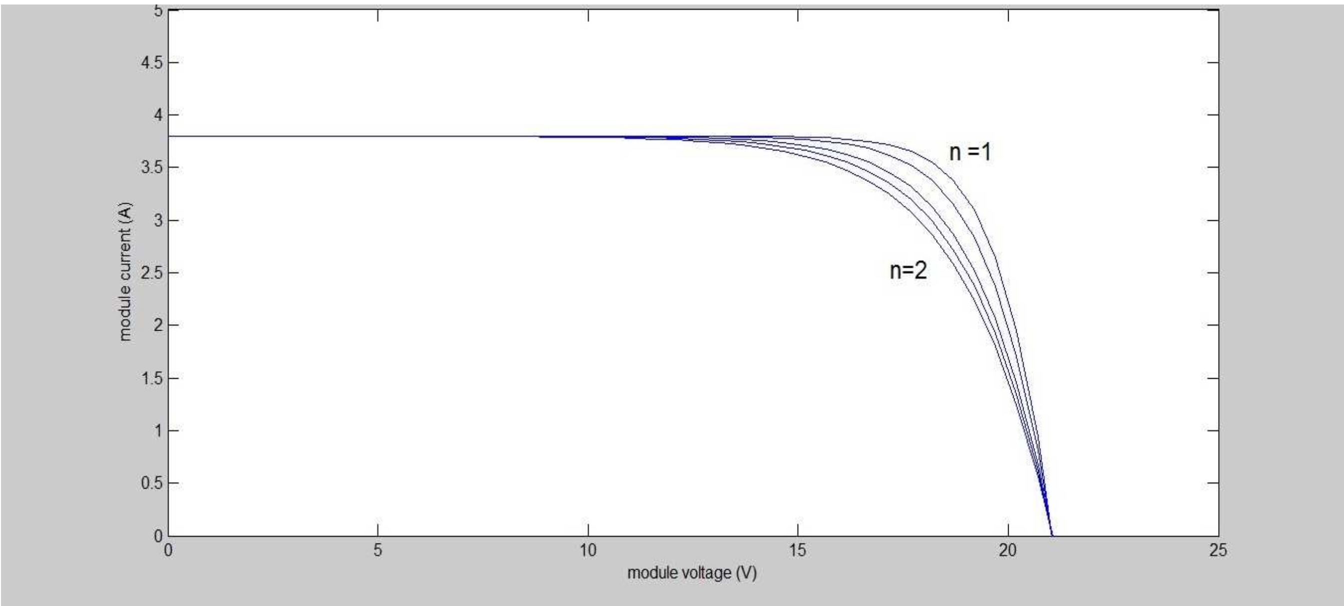

Fig. 17 depicts the variation of Module current with Module Voltage with the variation of diode stability factor n (n=1.00, 1.25, 1.50, 1.75 and 2) on the module at the constant irradiance and temperature

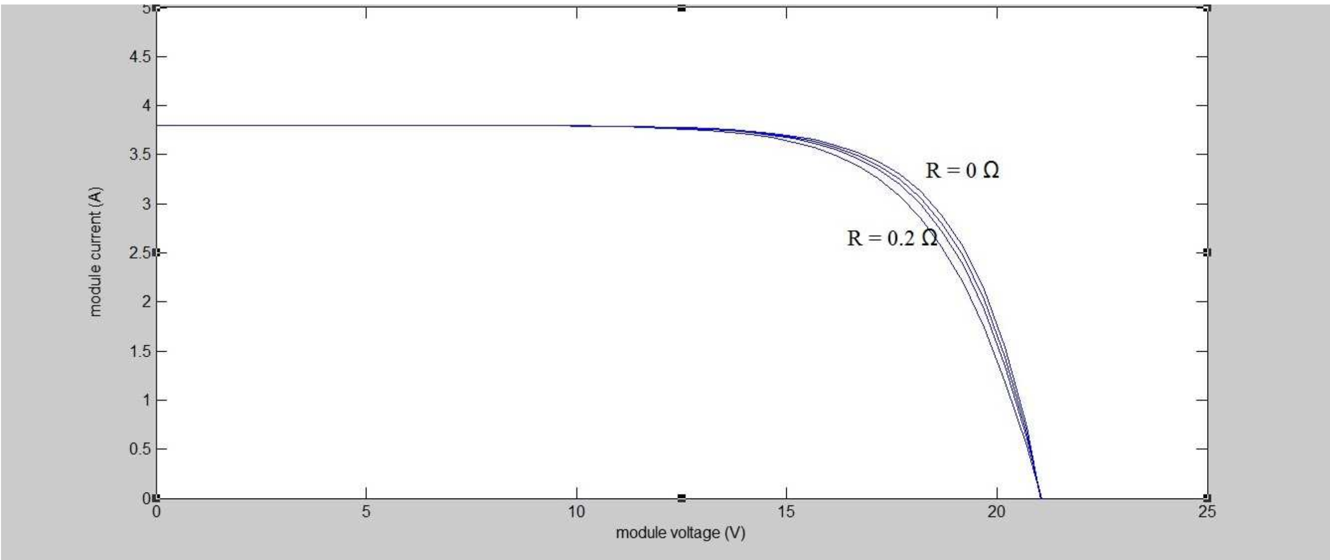

Fig. 18 depicts the variation of Module current with Module Voltage with the variation of series resistance R (R=0, 0.05, 0.2) on the module at the constant irradiance and temperature

6.2 Synchronous Buck Converter

To verify the suggested study of small rated PV system of 19.2 W with dc-dc synchronous buck converter unit of is demonstrated and examined in MATLAB/Simulink software. The parameters taken for simulation model study are assumed in the appendix. The performance of synchronous buck converter is analysed under different operating conditions and the corresponding results are presented here.

6.2.1 during Steady State Conditions

Fig. 19 depicts the steady state response of Synchronous Buck Converter for constant load. From Fig. 19(a) and fig 19(c), one can be see that, the output voltage and current of the converter settles in less than 6ms with the aid of above designed PI controller. The corresponding output voltage and current ripple are shown in Fig. 19(b) and Fig. 19(d) respectively and the voltage and current ripple of output voltage which is maintained very low with the help of the designed output capacitor which limits the output voltage and current ripple. Voltage stress across MOSFET 'M1' and MOSFET 'M2'are illustrated Fig. 19(e) and Fig. 19(f) with limited values according to desired value. Fig. 19(g) shows the response of input voltage from PV system which maintains constant at 12V.

6.2.2 During Step Load variation

Fig. 20 portrays the dynamic response of Synchronous Buck Converter during step changes in the load. From Fig. 20(a) an, we could observe that, the output voltage settles in more time than 10ms and maintained constant irrespective of the load variation from 1A to 1.5A as illustrated in Fig. 20(d) During load variations, the transients in output voltage persist and it settles within 20ms from the evidence of Fig.20(b). Voltage stress across MOSFET 'M1' and MOSFET 'M2'are illustrated Fig. 14(e) and Fig. 14(f) with limited values according to desired value. Fig. 14(g) shows the response of input voltage from PV system which maintains constant at 12V.

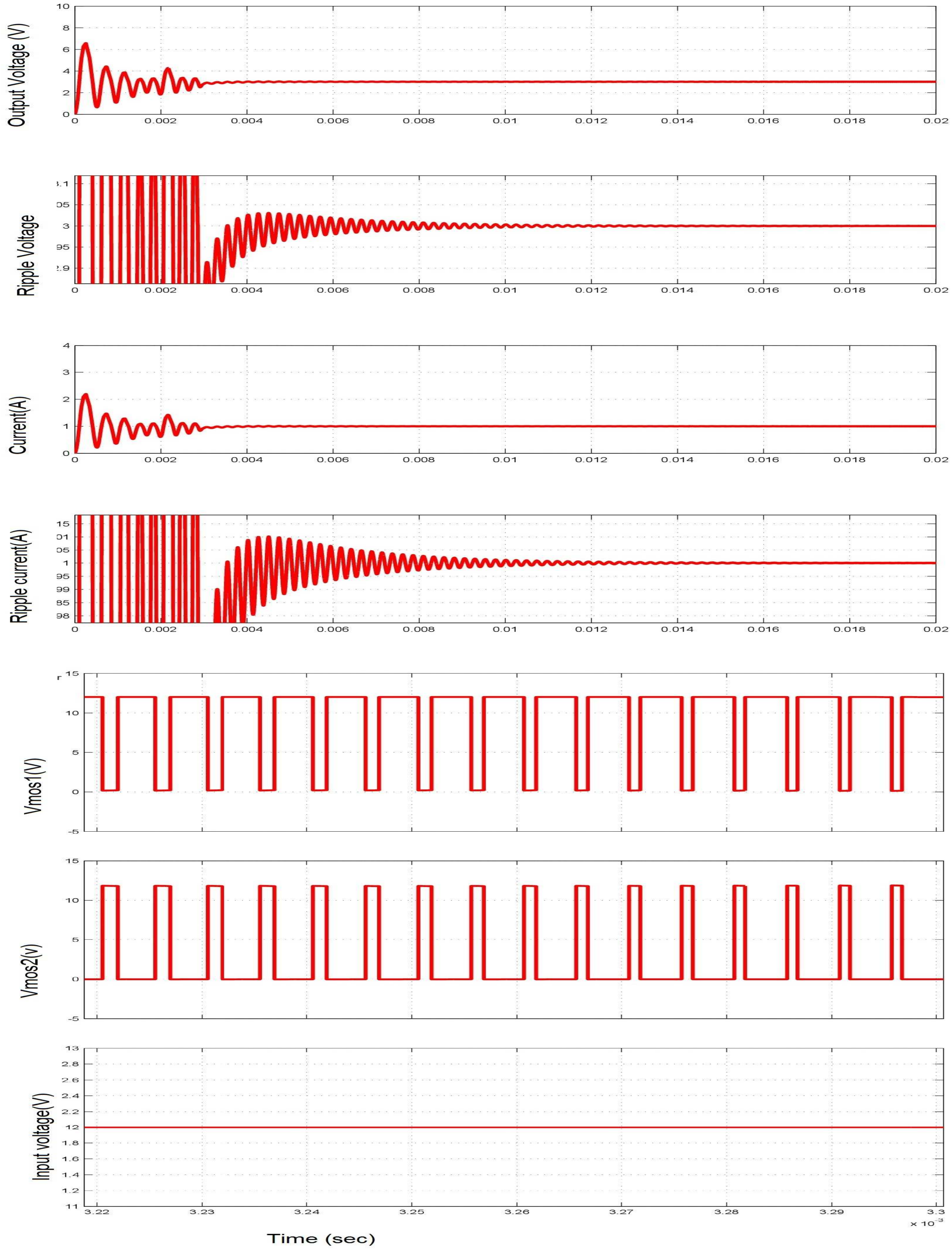

Figure 19: Response of Steady state of synchronous buck converter (a) output voltage (b) output voltage ripple (c) output current (d) output current ripple (e) voltage stress across MOSFET M1 (f) voltage stress across MOSFET M2 (g) input voltage

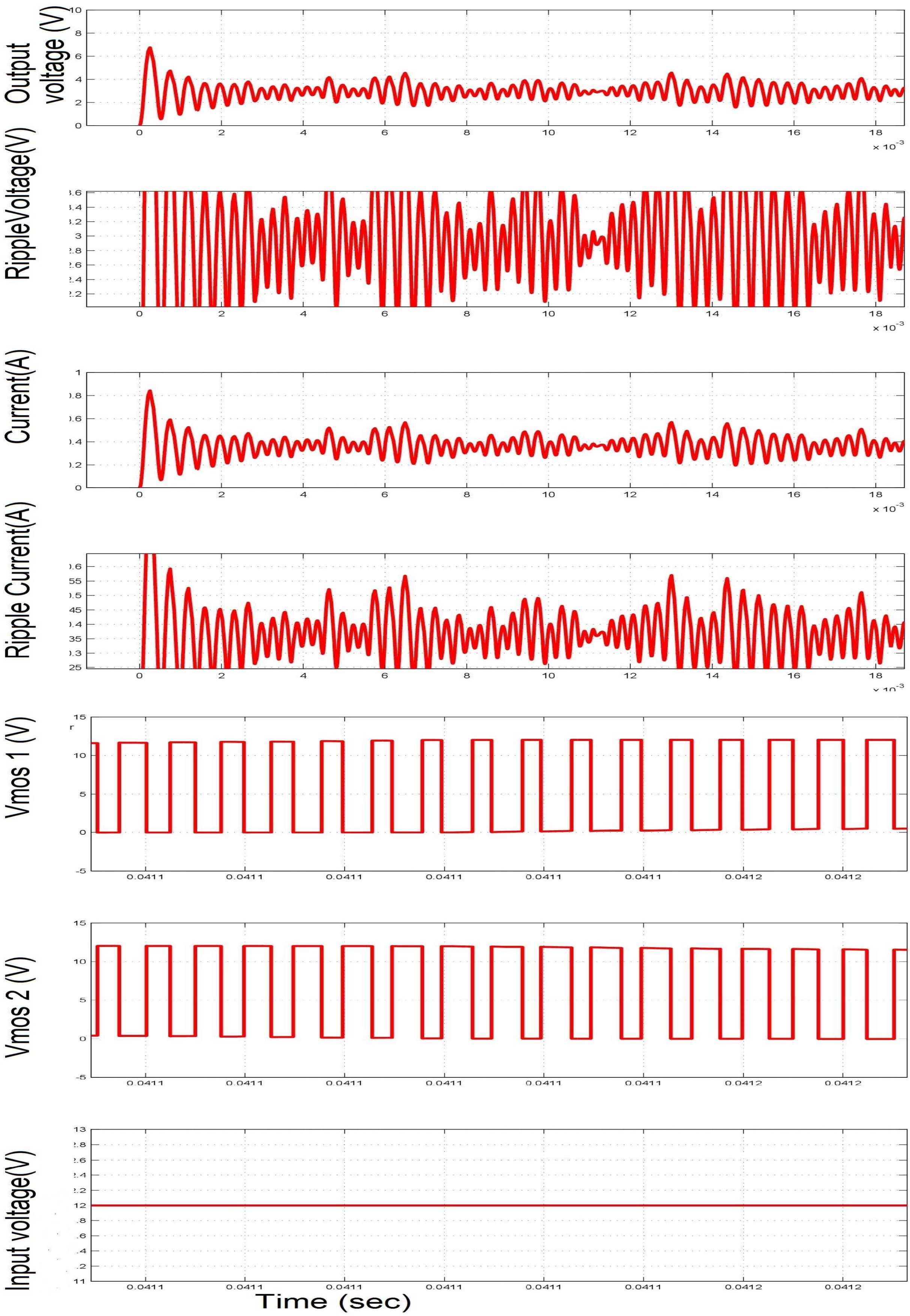

Figure 20: Response of step load variation of synchronous buck converter (a) output voltage (b) output voltage ripple (c) output current (d) output current ripple (e) voltage stress across MOSFET M1 (f) voltage stress across MOSFET M2 (g) input voltage.

6.3 Efficiency Comparison

Fig. 21 represents the efficiency comparison between two basic buck converter topologies. Since, voltage drop against MOSFET M2 is lower than the voltage drop across diode in buck converter topology. So, synchronous buck converter has low or less power dissipations and higher efficiency is obtained. From the figure it’s evident that, Synchronous Buck Converter has improved productivity than Conventional Buck Converter. The performance of synchronous buck converter at low load is higher than nonsynchronous buck converter. However, under higher load level, the efficiency also depends on duty cycle. However the trade-off for better efficiency in Synchronous Buck Converter is the price of additional MOSFET used. And also MOSFET saves space but complexity of control is increased because both switches should not conduct simultaneously (Any simultaneous conduction could cause to overload and damage the system called as ”shoot through ”.To get rid of this a suitable delay called ”dead-time” must be incorporated.)

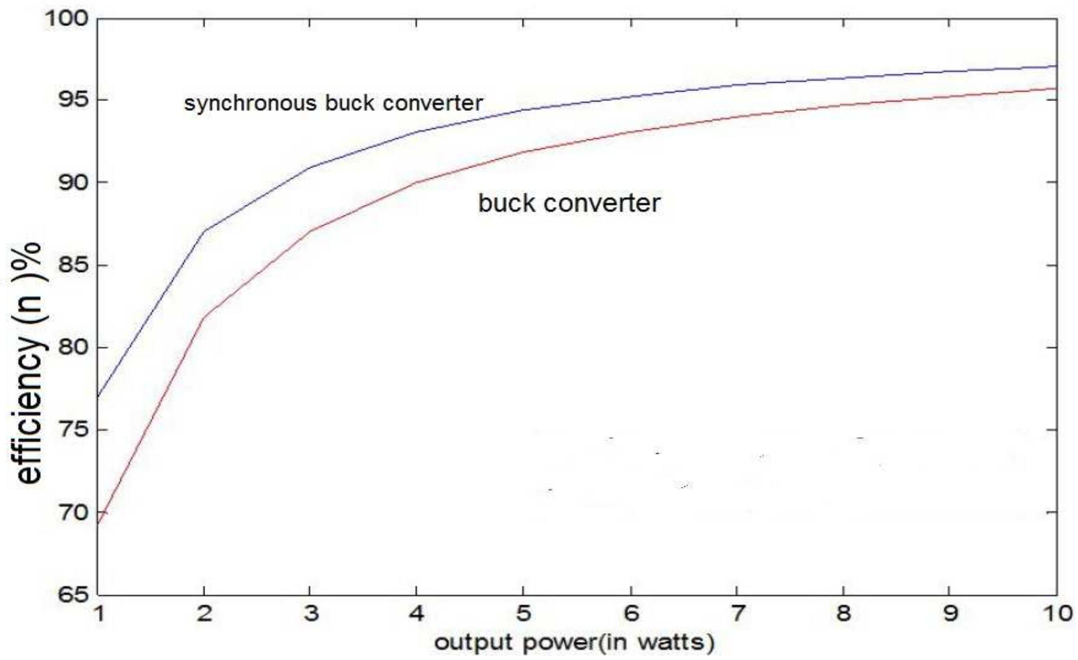

Figure 21: Efficiency Comparison between Synchronous Buck Converter and Conventional Buck Converter

6.4 Soft switching of synchronous buck converter

Soft switching technique is implemented on synchronous buck converter through matlab Simulink model and through driver circuit in hardware implementation. In this technique, two MOSFETS are used which are synchronized. The second MOSFET is used in place of diode so that conduction loss is minimised. But in this converter, no auxiliary circuit is present for reducing the switching losses. Figure 22 displays the respective waveforms of output current and voltage graphs. We can conclude from fig 22(a) and 22 (c) that there are little ripples in the voltage and graphs. Fig 22 (b) and 22 (d) shows the respective ripple voltage and current waveforms. Fig 22(e) and 22 (f) shows the delay in turn on and turn off time for MOSFET 1 and MOSFET 2. Fig 22(g) shows the input voltage waveforms.

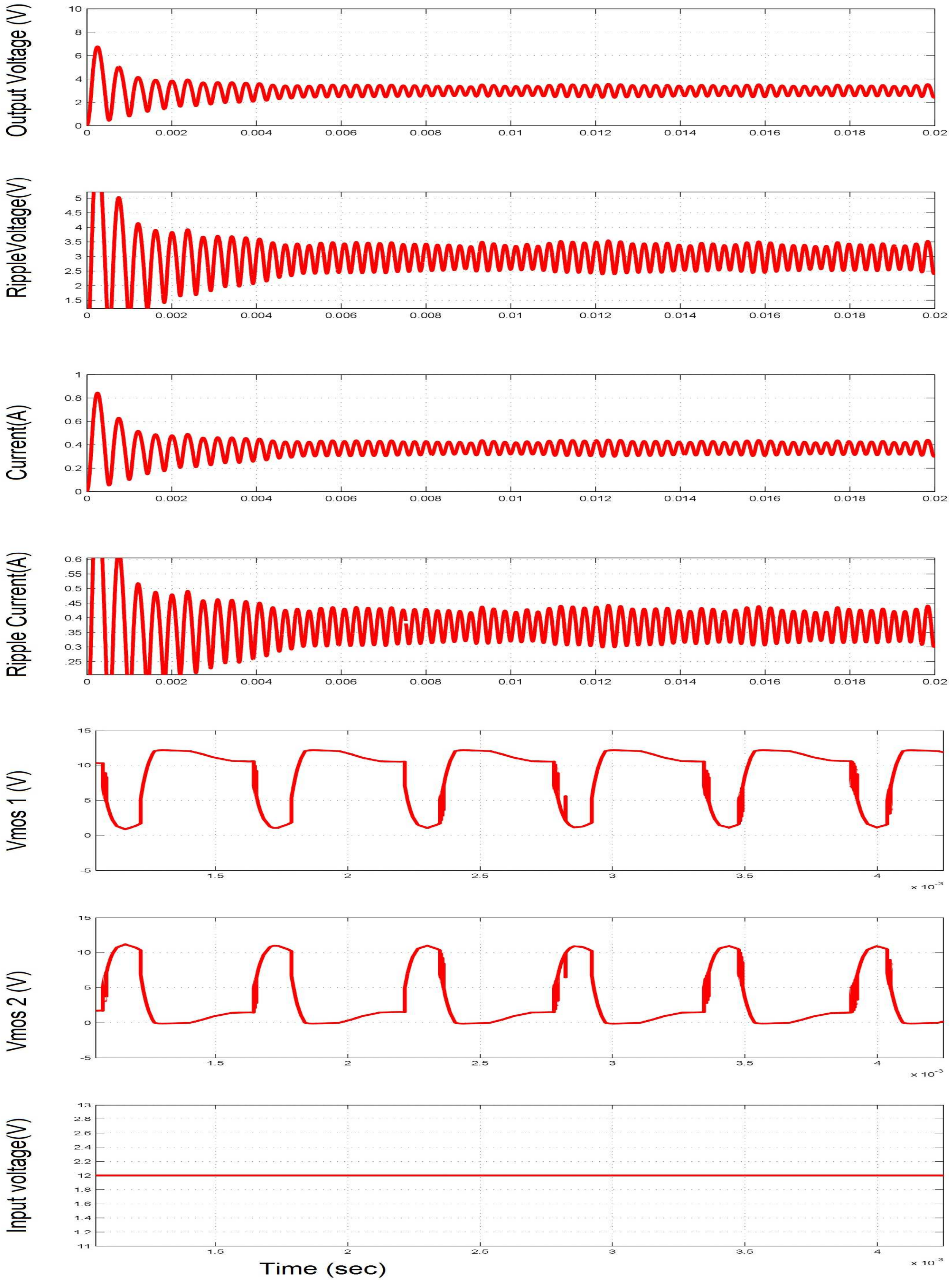

Figure 22: Soft switching of synchronous buck converter (a) output voltage (b) output voltage ripple (c) output current (d) output current ripple (e) voltage stress across MOSFET M1 (f) voltage stress across MOSFET M2 (g) input voltage.

6.5 Experimental Results

As discussed in previous chapters, various components of Synchronous Buck Converter are designed and bought through stores. The catalogue of items are given below:

- Ready-made Inductor of value around 40µH.
- Input Capacitor of value 100µF
- Output Capacitor of value 500µ
- Two N-Channel MOSFETS i.e. SiHG20N50C
- Two resistors of 1.5Ω each.
- Higher Voltage and High Speed power MOSFET or IGBT driver IR2213

As shown in the figure Fig. 18, experimental set up in laboratory is going to require
Voltage Source, CRO, Bread Boards, Connecting probes, Function generator etc., to carry out the experimental work intended.
We operate at 170 kHz and we use a duty cycle of 40 % for the flexible operation of the two MOSFETs.

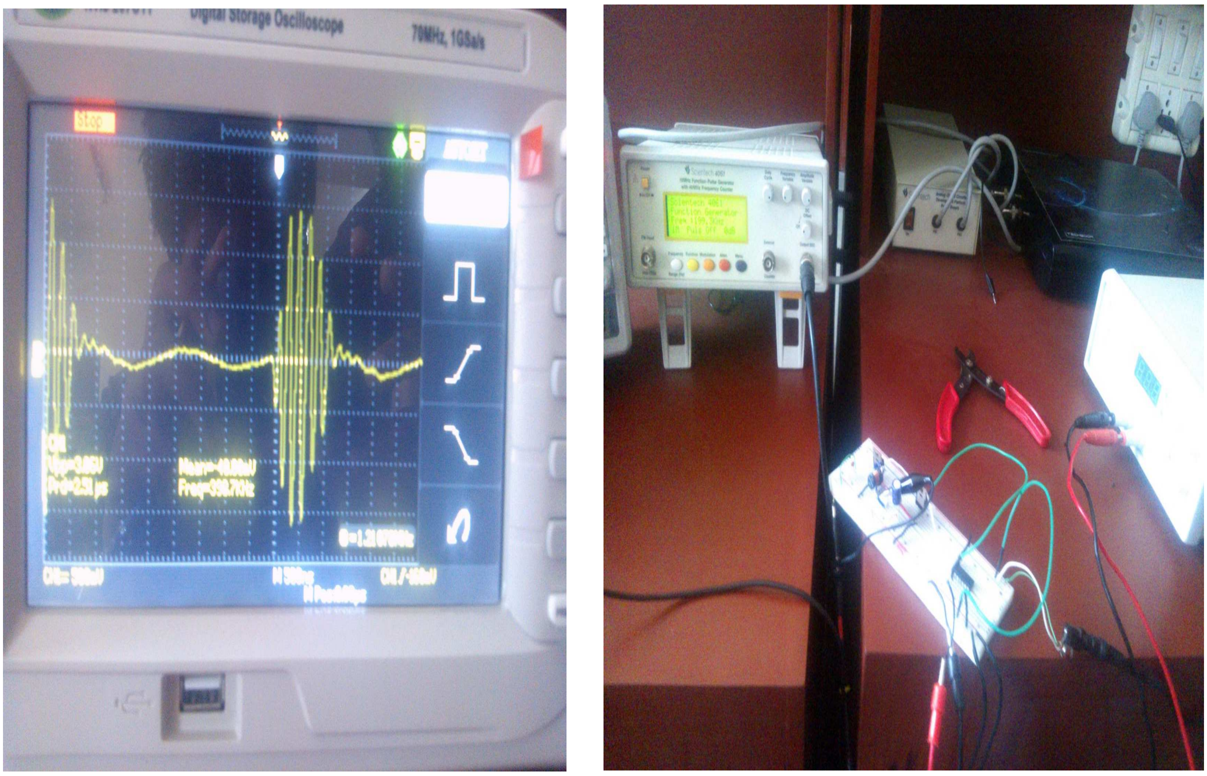

Figure 23: Experimental Set-up in Laboratory

6.5.1 Conventional Buck Converter

Input voltage shown in figure Fig. 19 is given through voltage source for conventional buck converter set-up. With the help of CRO we can observe the obtained output voltage which is shown in the figure Fig. 20, which concurs with the theoretical calculations of Buck Converter.

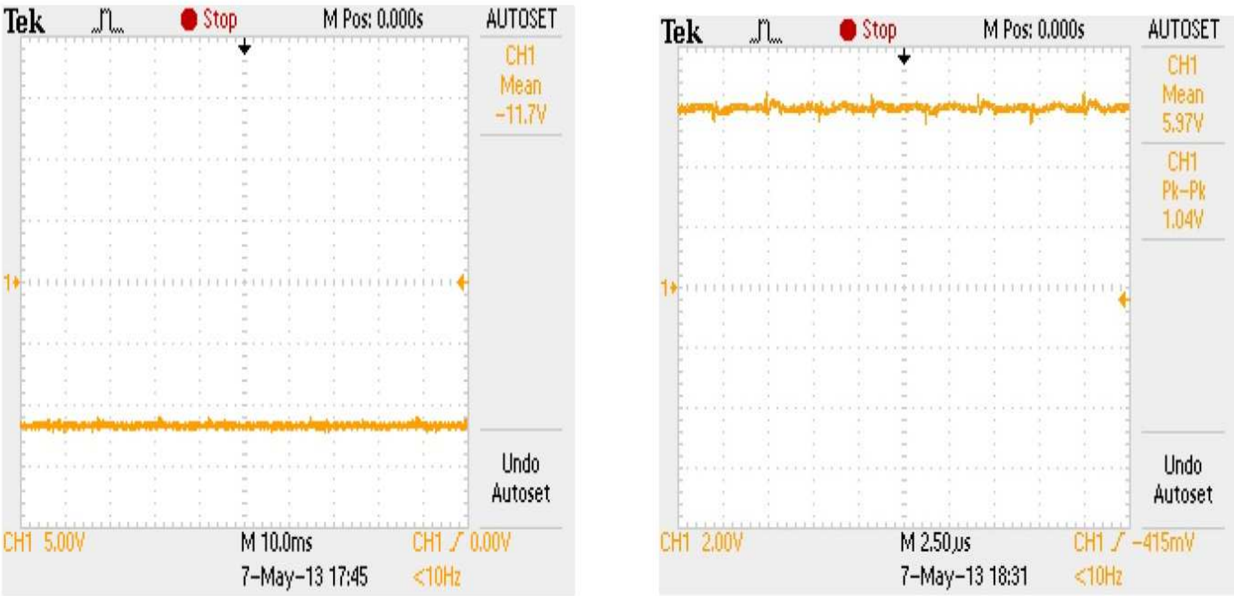

Figure 24 (a) Input voltage (b) output voltage of conventional buck converter.

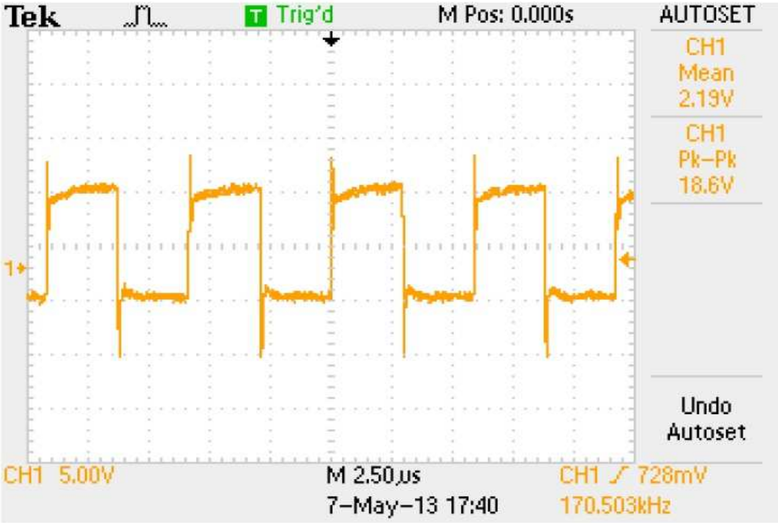

Figure 25 Voltage across MOSFET of buck converter

6.5.2 Synchronous Buck Converter

Input voltage same as given to Buck Converter as shown in figure Fig. 24 is given through voltage source for Synchronous buck converter set-up. With the help of CRO we can observe the obtained output voltage which is shown in the figure Fig. 2, which concurs with the theoretical calculations of Buck Converter. In figures Fig. 27 and Fig. 28 we can observe the voltage stress across the main MOSFET and Synchronous MOSFET respectively.

From the figures, Fig. 29 and Fig. 20 it is evident that the output voltages for both Conventional Buck Converter and Synchronous Buck Converter are identical for a given duty cycle. However, as studied theoretically there will be a great deal of difference in the efficiencies in the comparison of both converters, in which Synchronous Buck Converter is more effective and efficient than Conventional Buck Converter as shown in the figure Fig. 21.

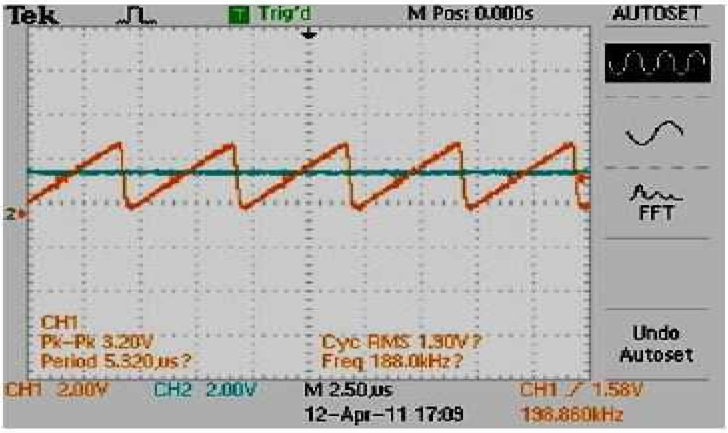

FIGURE 26: COMPARISON OF SAW TOOTH AND CONTROL VOLTAGE

The fig. 26 shows the pulse formation occurrence. The reference signal is matched with the sawtooth input and gate pulse is produced.

The gate pulse S1 is generated by relating the reference signal with clock signal, to produce the ON for a time t02, which can be observed in Fig 27

As it can be observed from the fig.28, the gate pulse of MOSFET S2 is get by relating the clock signal with the reference signal, to produce the pulse for time duration t7-t8.

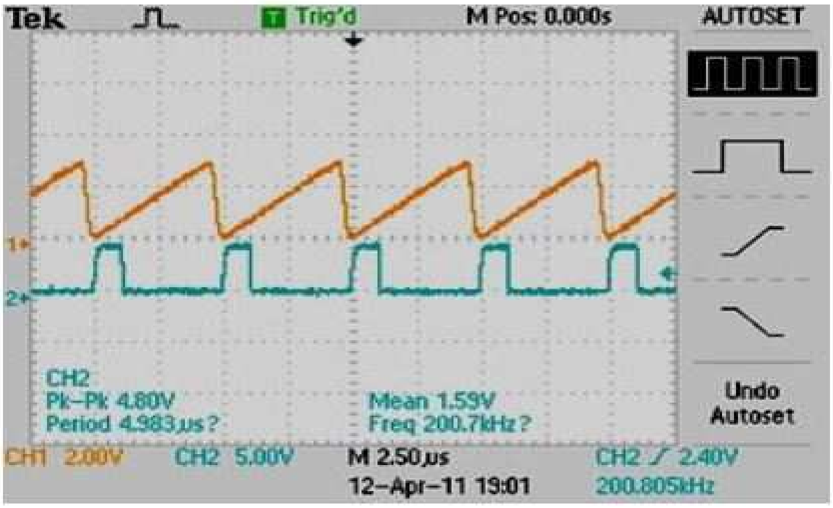

FIGURE 27: GATE PULSE FOR MOSFET S1

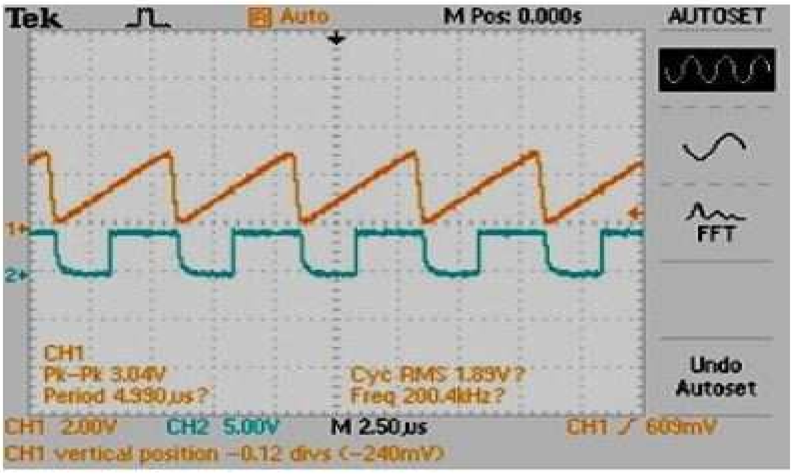

FIGURE 28: GATE PULSE FOR MOSFET S2

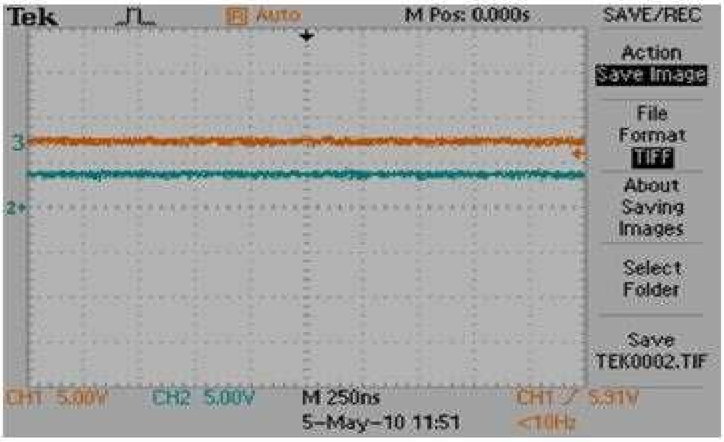

FIGURE 29: OUTPUT VOLTAGE OF SYNCHRONOUS BUCK CONVERTER

The response output of the synchronous buck converter that output a voltage of 3V when given an input of 8V, which is observed in the oscilloscope as in fig 29

Chapter-7 CONCLUSION AND FUTURE WORK

CONCLUSION

The no load P-V, P-I, I-V curves we got from the simulation of the solar panel designed in MATLAB simulink model describes in fact its constraint on the radiation levels and degree of hotness. The whole energy transformation scheme have been considered in MATLB-SIMULINK software. The many values of the voltage and current found have been conspired in the non-circuited I-V curves of the PV panel at isolation stages of 100 mW/cm2 and 200 mW/cm2. The voltage and current magnitudes occur on the characteristics screening that the link of the PV panel with the Buck converter is appropriate. Though the enactment of the photovoltaic device be contingent on the spectral circulation of the solar emission. As solar panel is cast-off as a foundation of energy, it is essential to usage a extreme power point tracker to guarantee negligible energy loss. The maximum power point tracker is applied to find the extreme power point in our synchronous buck converter design. The core idea of paper is to use Soft Switching technique for modelling of converter which decides precise values for PI controller used in control circuit. Synchronous buck converter with closed loop PI controller precisely improved the dynamic response of the system during load as well as source variation with reduced voltage and current ripple. Furthermore, the circuit construction is modest and more economic relative to other control practices where great amount of apparatuses is required. Further, the converter design and its efficiency also determined. As results, the effectiveness of synchronous buck converter is advanced than conventional dc-dc buck converter for same power rating.

FUTURE WORK:

The converter designed in this project operates at 200 KHz. However, for faster response at higher frequencies with easily customisable control, FPGA implementation can be made and can be integrated with micro controller control for more stability in output at various conditions. Such low cost systems with less error due to digital operation can be used to operate low power high current devices and also the isolated house power can be managed with these microcontroller based systems which has an added advantage of flexibility and ability to interact with other devices. Thus the freedom to get electricity anywhere and the adaptability of micro controllers to suit many conditions easily can be exploited to make such portable systems in an effective and user-friendly manner.

7. References

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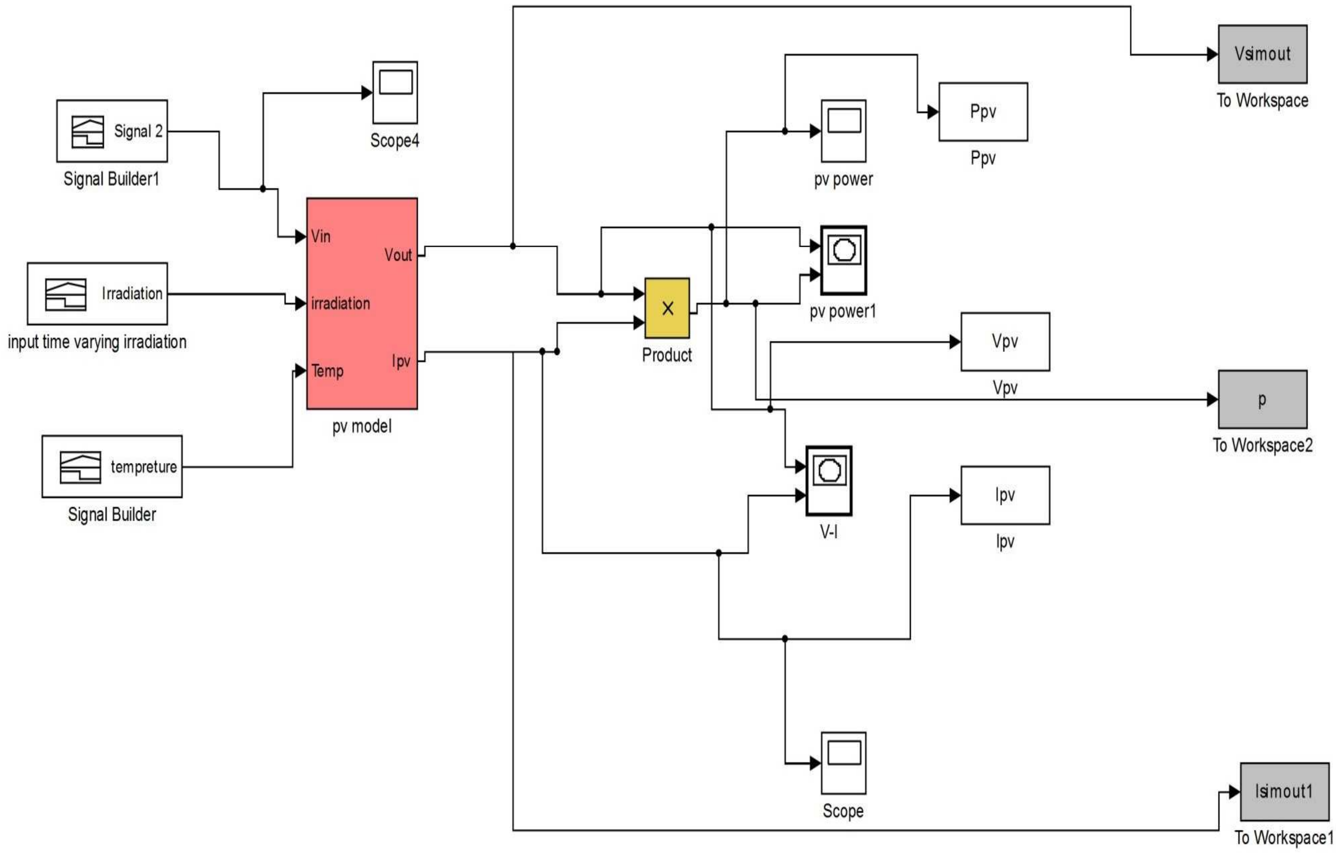
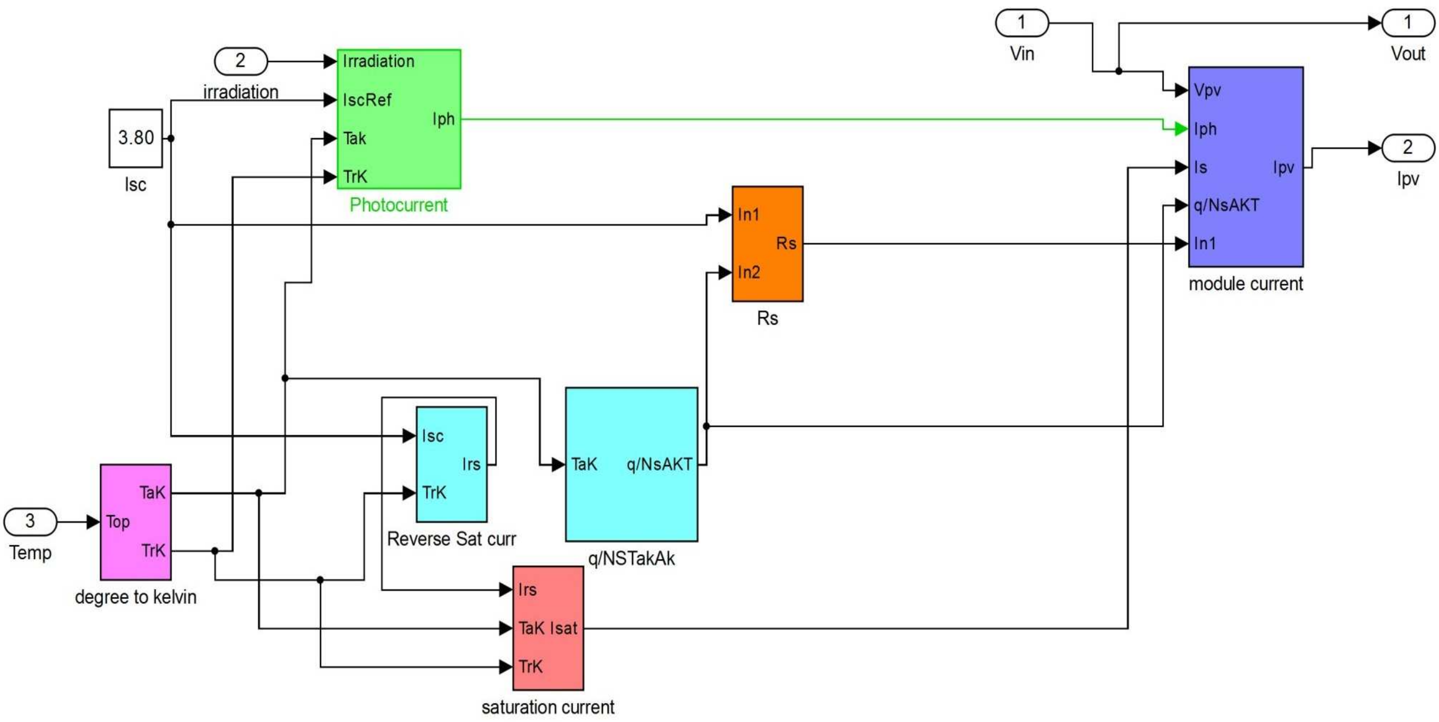
APPENDIX

MATLAB SIMULINK MODELS

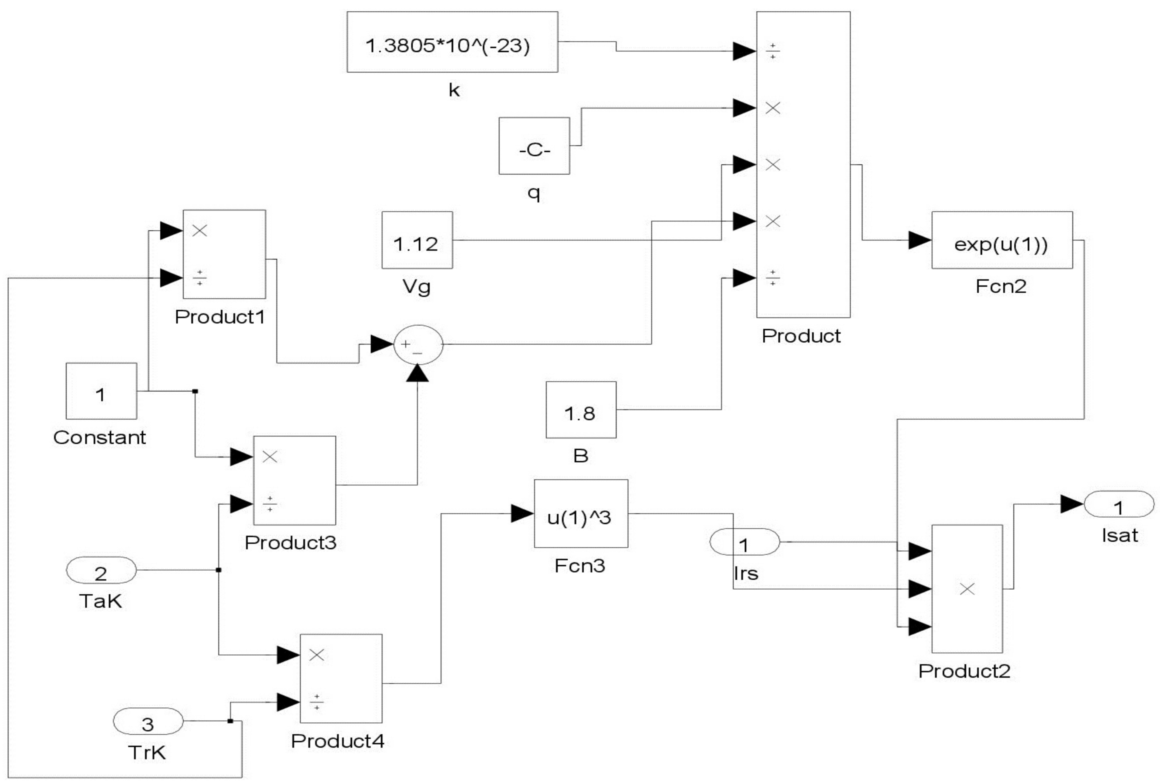
1. PV ARRAY MODEL



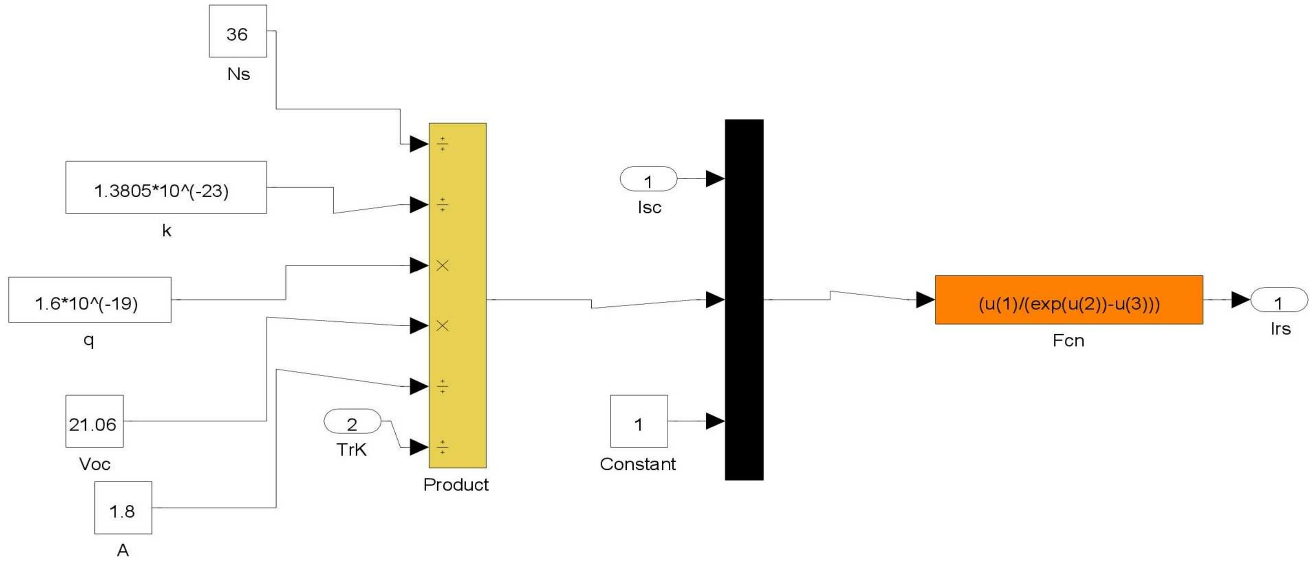
PHOTOVOLTAIC SIMULATION MODEL



PV MODEL BLOCK

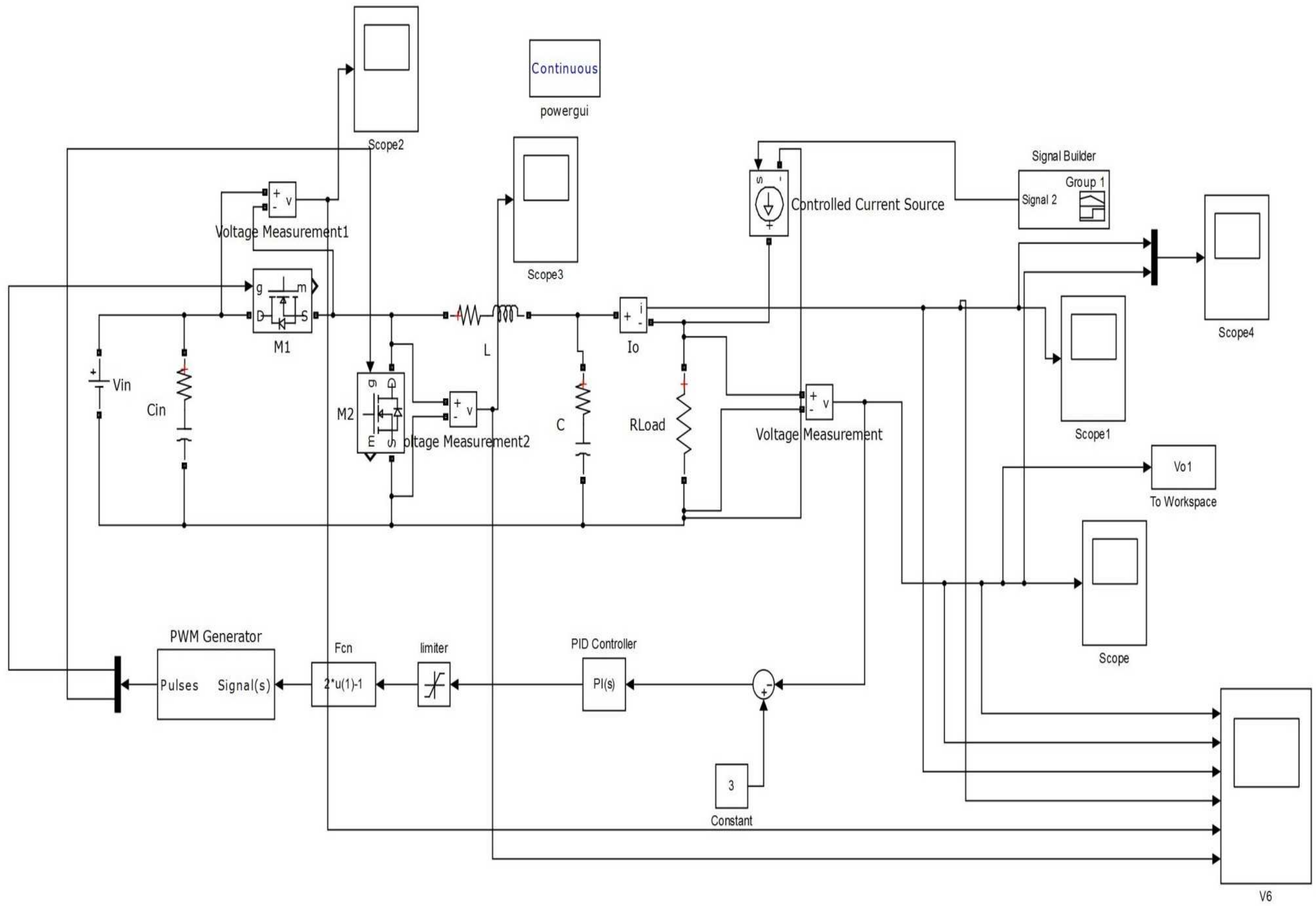


SATURATION CURRENT BLOCK

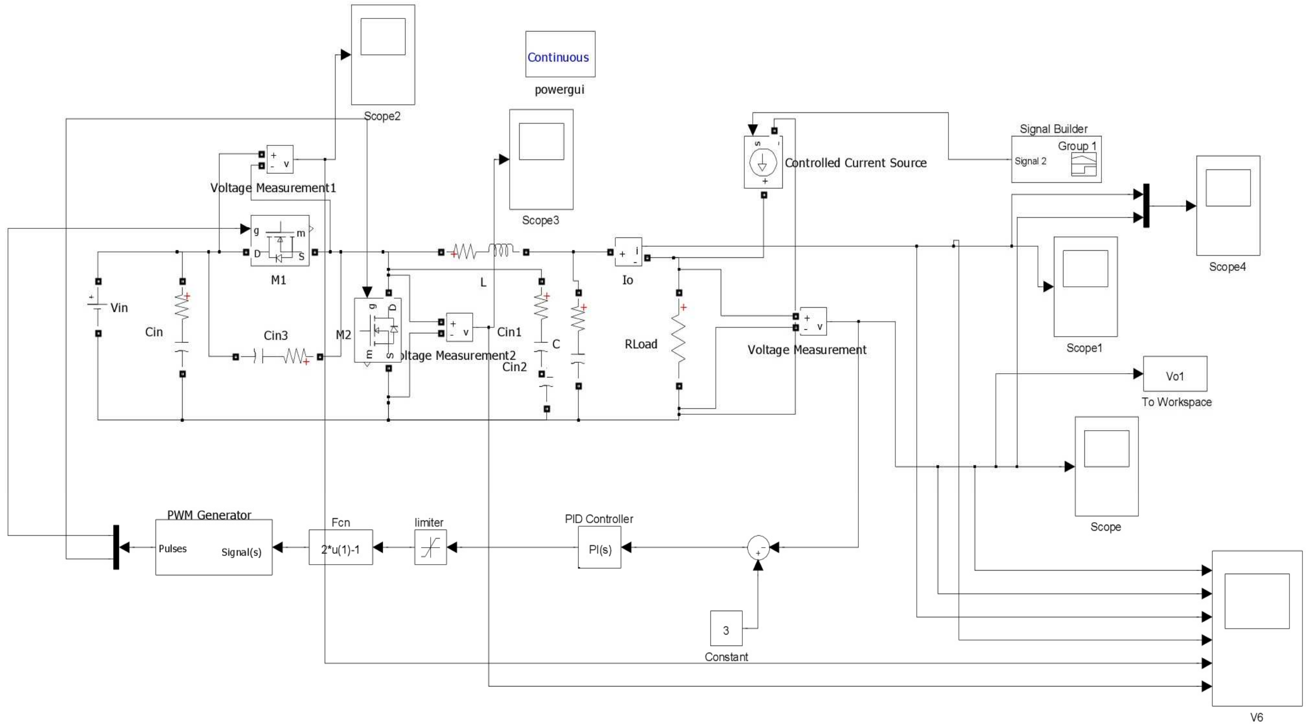


REVERSE SATURATION CURRENT BLOCK

2. SUNCHRONOUS BUCK CONVERTER MODEL



SIMULINK MODEL OF SYNCHRONOUS BUCK CONVERTER



SOFT SWITCHING SIMULINK MODEL OF SYNCHRONOUS BUCK CONVERTER